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Old O-Field is a hazardous waste disposal site at the Aberdeen Proving Ground-Edgewood Area, Aberdeen, Maryland, which has contaminated the underlying groundwater. The contaminated groundwater is collected and treated at the Old O-Field Groundwater Treatment Facility (GWTF) with subsequent discharge to the Gunpowder River. An in-line automated fish ventilatory biomonitoring system was installed at the GWTF to monitor the effluent for unexpected toxicity as it is discharged.

A number of out of control events (stressed fish) occurred during the study (June 23, 1995 to March 31, 1996). The total number of days the system obtained out of control responses was 21.0 d. Explanations for the out of control responses were available for 20.6 d. No obvious explanations were apparent for 0.5 d. The out of control responses occurred from 1) changes in effluent water quality; 2) power failures; or 3) a proportional diluter failure. Changes in effluent water quality accounted for 89.2% of the total out of control responses with explanation. Loss of power and a diluter malfunction accounted for 5.9% and 4.9% of the out of control responses with explanation, respectively. Out of control responses with no explanation occurred 0.2% of the time or 0.5 d during the study. No acute toxicity attributable to the GWTF effluent quality occurred during the study.

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FOREWORD

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( ) In conducting research utilizing recombinant DNA technology, the investigator(s) adhered to current guidelines promulgated by the National Institutes of Health.

V.T. Burton
Principal Investigator's Signature

8-30-96
Date

CERTIFICATION OF TECHNICAL DATA CONFORMITY

The ventilatory biomonitoring system was developed, installed, and field tested by the U.S. Army Biomedical Research and Development Laboratory (USABRDL). All standard operating procedures for the system were developed by USABRDL. Computer and program support, fish, and other operating items were supplied by USABRDL. All decisions concerning changes in operation of the system were implemented by and/or made under the direction of USABRDL. Starting April 4, 1995, the University of Maryland at College Park (UMCP) began to provide limited technical labor support for the ventilatory biomonitoring system. Technical labor support for the day to day operation of the biomonitoring system was provided by UMCP, under USABRDL's supervision, on July 3, 1995, and continued through the writing of the report.

The annual report summarizes the operational phase of the effluent ventilatory biomonitoring system for the period June 23, 1995 to March 31, 1996. Most of the data used to write the report were provided by USABRDL. A number of data interpretations and explanations of response events were also provided by USABRDL and are cited, where appropriate, in the report. Roy F. Weston, Inc. supplied some Old O-Field Groundwater Treatment Facility operation data used in the report. UMCP was not tasked to conduct any quality assurance/quality control (QA/QC) analyses of the data used in the report.

The contractor, UMCP, hereby certifies that, to the best of its knowledge and belief, the report delivered herewith under Contract No. DAMD17-92-C-2066 complies with all requirements of the contractor.

Date: August 30, 1996

Name and Title of Certifying Official: D.T. Burton

Dennis T. Burton, Ph.D.
Senior Research Scientist

EXECUTIVE SUMMARY

Old O-Field is a hazardous waste disposal site at the Aberdeen Proving Ground-Edgewood Area which has contaminated the underlying groundwater. The contaminated groundwater is being collected and treated at the Old O-Field Groundwater Treatment Facility (GWTF) with subsequent discharge to the Gunpowder River. An in-line automated fish ventilatory biomonitoring system has been installed at the GWTF to monitor the effluent for toxicity as it is discharged to the receiving stream. The system is used as an early warning indicator of water quality conditions that may exceed acceptable discharge limits set by state and federal law. The system continually monitors the ventilation and body movement patterns of fish. Early warning stress is characterized by changes in ventilatory and movement patterns and is used to identify developing acute toxicity of the effluent.

The ventilatory biomonitoring system was developed, installed, and field tested by the U.S. Army Biomedical Research and Development Laboratory (USABRDL). All standard operating procedures (SOPs) for the system were developed by USABRDL. The objective of this report is to evaluate the operation of the effluent ventilatory biomonitoring system at the GWTF. The biomonitoring system was installed during the first quarter of 1995. The system was run in a start-up mode from March 27, 1995 to June 22, 1995. The start-up period was used to integrate and/or adjust the detection parameters of the system with operational parameters at the GWTF. The data from the start-up period are not summarized in this report. This report covers the operational period from June 23, 1995 to March 31, 1996.

Biomonitoring Responses

The Aquatic Biomonitoring Program data acquisition system was on-line for 272.9 d out of a total of 282.4 d. Data were not taken for 9.5 d because the data acquisition system was off-line for various reasons (e.g., Hydrolab® calibration, data transfer, program errors, etc.). The system was operated in an auxiliary mortality monitor (acute toxicity only) mode for 17.4 d. No acute toxicity occurred from changes in effluent quality during the periods the system was operated in an auxiliary monitor mode.

A number of out of control events occurred during the operational period. The total number of days the system recorded out of control responses was 21.0 d when the system was on-line and was not in an auxiliary mortality monitor mode. Explanations for the out of control responses were available for 20.6 d of the 21.0 d. No obvious explanations were apparent for 0.5 d. The 0.1 d discrepancy between 20.6 d and 0.5 d is due to rounding error.

The out of control responses occurred from one of the following three reasons: 1) changes in effluent water quality; 2) power failures; or 3) a proportional diluter failure. Changes in effluent water quality accounted for 89.2% of the total out of control responses with explanation. Loss of power and a diluter malfunction accounted for 5.9% and 4.9% of the out of control responses with explanation, respectively.

The majority of the out of control response events for which explanations were documented have been corrected and should not occur in the future. The water quality events which have been corrected (78.5% of the events) included 1) a high effluent conductivity problem; 2) a sudden drop in effluent temperature because the return line on the downstream aeration tank was not secured and the water in the tank passed to the drain rather than being recirculated and 3) responses caused by shifts in water quality when fish were switched from control water to effluent or effluent to control water. The remaining non-water quality out of control response events occurred as a result of 1) sustained losses of power because the GWTF backup generator did not start; the backup generator ran out of fuel; and/or power to the biomonitoring facility was interrupted and 2) the failure of a diluter. The majority of the backup generator failure problems can most likely be solved by appropriate GWTF maintenance and fueling of the generator. It is not clear how a future diluter failure can be eliminated since the diluters are routinely serviced and calibrated.

A few out of control responses occurred which did not have an apparent explanation. Out of control responses with no explanation occurred 0.2% of the time or 0.5 d during the period June 23, 1995 to March 31, 1996. A total of 16 events occurred. Twelve of the 16 events lasted 1 h or less. Three of the four events >1 h lasted 1.25 h; the fourth had a duration of 1.75 h.

Possible solutions for the out of control responses with no apparent explanation are not obvious. Twelve of the 16 out of control responses for which there was no apparent explanation lasted 1 h or less. It may be appropriate to evaluate whether or not events ≤1 h should be used as early warning indicators of potential GWTF toxicity. It may be possible to use some type of time series/neural network analyses to predict when the random events may occur. The evaluation should also consider whether or not the GWTF should stop discharging effluent during these short out of control periods, particularly, isolated 15-min events.

Effluent and Control Water Quality

Effluent and control water quality were continuously monitored by an in-line Hydrolab® system. The values generally fell within the ranges set in the Aquatic Ventilatory Program (i.e., temperature = 23-27°C from June 23, 1995 to February 29,

1996 and 21-25°C for March 1996; pH = 6.5-8.5 S.U.; and DO = 3-12 mg/L). However, a number of out of limit excursions occurred. The largest number of excursions occurred with temperature. With the exception of June in which no temperature excursions occurred, the out of limit excursions ranged from a low of 2% in March to a high of 46% in November. The temperature excursions can be reduced by instituting better control measures at the level of the two aeration tanks which are also used to regulate effluent and control water temperatures before they enter the ventilatory exposure system.

A number of pH excursions occurred in the effluent during the months of June, July and September; none occurred during the last two quarters of the study. It appears that pH excursions are not an on-going problem.

Out of limit DO excursions (outside the range of 3-12 mg/L) occurred during the months of June, July, and August. Several out of limit low DO readings occurred. In most of the cases, however, the DO excursions were above 12 mg/L. A number of the high readings approached an order of magnitude above saturation at 25°C. The excessively high values show that the oxygen sensor in the Hydrolab® system had 1) a recurring operational problem or 2) some material(s) present in the effluent may have interfered with the normal functioning of the probe. The high DO readings were corrected by replacing the oxygen probe solution, membrane, and re-calibrating the sensor.

DO concentrations <5 mg/L trigger GWTF regulatory compliance actions. Out of compliance Hydrolab® DO readings occurred every month except November. In contrast, manually measured DO values were above 5 mg/L for all months except one reading in August; one reading in September; and five readings in March. The discrepancies between the Hydrolab® and manual DO reading needs to be resolved. Because of the large number of high and low (<5 mg/L) DO readings obtained by the Hydrolab® system relative to the small number of manual DO excursion readings, the operation of the Hydrolab® oxygen probe should be re-evaluated. Likewise, a number of "odd" conductivity measurements, which were corrected by re-calibrating the sensor, indicate that a problem also exists with the conductivity sensor.

In summary, a number of effluent water quality excursions occurred. No acute toxicity attributable to the GWTF effluent quality occurred during the period June 23, 1995 to March 31, 1996. An evaluation of the out of control response events <1 h in duration, for which there are no apparent explanations, should be conducted to determine whether or not the events should be used as early warning indicators of potential GWTF operational problems. Likewise, the performance of the Hydrolab® system, in particular the oxygen sensor, should be re-assessed to resolve the discrepancy between the Hydrolab® and manual DO readings.

ACKNOWLEDGEMENTS

We thank Mr. Tommy Shedd (COR) and Mr. Bob Bishoff of USABRDL and Mr. Mark Widder of GeoCenters, Inc., for their help in compiling the data used in the report. We would also like to thank Ms. Rosanne Cooke, Mr. Kevin Deeny, and Mr. Chris Dougherty of Roy F. Weston, Inc., for providing GWTF data for the report. We acknowledge USABRDL for supporting the project through U.S. Army Contract No. DAMD17-92-C-2066. This report is Scientific Article No. A7908, Contribution No. 9243 from the Maryland Agricultural Experiment Station.

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SECTION 1

INTRODUCTION

Old O-Field is a hazardous waste disposal site at the Aberdeen Proving Ground-Edgewood Area which has contaminated the underlying groundwater. The contaminated groundwater is being collected and treated at the Old O-Field Groundwater Treatment Facility (GWTF) with subsequent discharge to the Gunpowder River. An in-line automated fish ventilatory biomonitoring system has been installed at the GWTF to monitor the effluent for toxicity as it is discharged to the receiving stream (Shedd et al., 1995). The system is used as an early warning indicator of water quality conditions that may possibly exceed maximum acceptable discharge limits set by state and federal law. The system continually monitors the ventilation and body movement patterns of fish. Changes in ventilatory and movement patterns are predictive of possible developing acute toxicity of the effluent (ASTM, 1996).

The ventilatory biomonitoring system was developed, installed, and field tested by the U.S. Army Biomedical Research and Development Laboratory (USABRDL). All standard operating procedures (SOP) for the system were developed by USABRDL. Computer and program support, fish, and other operating items are currently supplied by USABRDL. Starting April 4, 1995, the University of Maryland at College Park (UMCP) began to provide limited technical labor support for the ventilatory biomonitoring system. Technical support for the day to day operation of the biomonitoring system was provided by UMCP under USABRDL's supervision, on July 3, 1995, and has continued to the present time.

The primary objective of this report is to assess the operation of the effluent ventilatory biomonitoring system at the GWTF. The biomonitoring system was installed during the first quarter of 1995. The system was run in a start-up mode from March 27, 1995 to June 22, 1995. The start-up period was used to integrate and/or adjust the detection parameters of the system with operational parameters at the GWTF. The data from the start-up period are not summarized in this report. This report covers the operational period from June 23, 1995 to March 31, 1996.

SECTION 2

OLD O-FIELD GROUNDWATER TREATMENT FACILITY DESCRIPTION

A detailed discussion of the Old O-Field site, groundwater extraction system, and operation of the groundwater treatment facility is given in Weston (1994). The following is a brief description of the Old O-Field site, groundwater extraction system, and operation of the groundwater treatment facility which was taken from Weston (1995a).

2.1 Site Background and History

Old O-Field is a 2 hectare (5 acre) hazardous waste disposal site located on the lower half of the Gunpowder Neck in the Edgewood Area of Aberdeen Proving Ground. The site is bordered by surface water on three sides: Watson Creek to the north and east, and the Gunpowder River to the west.

During the 1940s and 1950s, 35 unlined pits and trenches were dug within Old O-Field and used for the disposal of chemical warfare agents, munitions, contaminated equipment, and miscellaneous hazardous waste. The presence of chemical agent wastes, munitions, and other hazardous materials has impacted the groundwater at Old O-Field and the interconnecting surface water in Watson Creek (Weston, 1995a).

Pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA/Superfund), the Old O-Field was listed on the National Priorities List (NPL) as a result of its history of on-site hazardous waste disposal.

Several decontamination and cleanup operations were performed at Old O-Field from 1949 through the early 1970s. The most notable of these efforts was carried out in 1949 when $\approx 1.19 \times 10^5$ L (1,000 barrels) of decontaminating agent was applied to the field in an attempt to detoxify mustard gas that had been scattered over the site by several spontaneous detonations. The decontaminating agent contained approximately 95% 1,1,2,2-tetrachloroethane. Elevated levels of tetrachloroethane and its degradation products have been identified in the groundwater at Old O-Field; thus, it appears likely that this effort actually resulted in groundwater contamination with chlorinated hydrocarbon compounds.

Major areas of impact on the groundwater are northeast and east of Old O-Field. Both the water table and the upper confined aquifer contain groundwater that is impacted. In general, the highest contaminant concentrations have been found in the water table aquifer (Weston, 1995a).

The U.S. Army Corps of Engineers, Aberdeen Area Office (CEAAO), under an interagency agreement negotiated with the U.S. Environmental Protection Agency (EPA) and the Maryland Department of the Environment, is providing interim environmental remediation support to the Aberdeen Proving Ground Environmental Conservation and Restoration Division. In support of this effort, CEAAO retained Roy F. Weston, Inc. to design, install, and operate the Interim Remedial Measure for Operable Unit One for Old O-Field, which entails extraction and treatment of contaminated groundwater for plume migration control. The Record of Decision for Operable Unit One was signed by EPA in September 1991. Subsequently, as a result of changes in the proposed remedy during detail design, Weston prepared an Explanation of Significant Differences (ESD) document for CEAAO in July 1994. The ESD document was reviewed and approved by EPA. This document is currently being used as the operations and maintenance manual for the Old O-Field groundwater and treatment system.

2.2 Overview of the Groundwater Extraction Facilities

Thirteen extraction wells have been installed in the water table aquifer to capture the contaminated groundwater plume and convey it to the groundwater treatment facility which is discussed in more detail in Weston (1995a). Pump tests were performed on the 13 wells to determine the flow rate necessary to maintain hydraulic control in order to capture groundwater contaminants. Well field performance testing showed that hydraulic control could be maintained by pumping 10 of the 13 water table aquifer extraction wells. Three extraction wells were also installed in the upper confined aquifer. These wells are not scheduled for pumping until sufficient data are collected to evaluate the need for pumping the upper confined aquifer.

2.3 Basis of Design for the Groundwater Treatment System

The original conceptual design of the GWTF was developed for a flow rate of ≈114 L/min (30 gpm). The optimal groundwater extraction scenario, however, consists of pumping the 10 extraction wells that are located in the water table aquifer at a total combined rate of ≈38 to 49 L/min (10 to 13 gpm). Discussions with CEAAO and base personnel concluded that the nominal cost reduction from downsizing the treatment capacity would not justify the loss of flexibility provided by a 114 L/min system; therefore, the design capacity of the groundwater treatment was retained at 114 L/min. In order to establish a basis for design, a conservative estimate of the chemical characteristics of the influent was established as described in Weston (1995a).

2.4 Process Description

A detailed description of the GWTF process, including process flow diagrams, is given in Weston (1994). Briefly, groundwater pumped from the extraction wells is collected and stored in two equalization tanks. The tanks allow the extraction system to operate independently from the treatment system. Lime slurry (calcium hydroxide) is added and mixed with the influent groundwater in a lime reaction tank. This raises the pH and causes heavy metals to precipitate. These conditions also form calcium carbonate, which precipitates and removes hardness and alkalinity from the groundwater. Solids generated as a result of this reaction settle in an inclined plate clarifier. Solids removed by the clarifier are transferred to a sludge holding tank. Solids from the sludge holding tank are dewatered by means of a plate and frame filter press. The filter cake generated from this process is stored for off-site disposal.

The clarified effluent is neutralized with sulfuric acid in a first-stage neutralization. Neutralization also provides a more optimum pH for the precipitation of aluminum. Residual solids present after acid addition to the clarifier effluent are removed by a continuous backwash upflow sand filter. Backwash from the sand filter is transferred to a sludge holding tank. Effluent from the sand filter is discharged to either intermediate holding tanks or to an air stripper. The function of the air stripper is to remove the majority of volatile organic compounds (VOCs) present in the groundwater. The gaseous emissions from the air stripper pass through a vapor-phase granular activated carbon (GAC) system to adsorb the VOCs stripped from the groundwater.

Liquid effluent from the air stripper passes through two cartridge filters arranged in parallel. The function of the filters is to remove solids that may be present in the air stripping effluent. Hydrogen peroxide is added downstream of the cartridge filters prior to treatment of the effluent in an ultraviolet light catalyzed oxidation system (UV-OX). When exposed to UV light, hydrogen peroxide forms highly reactive hydroxyl radicals that break the structural bonds of organic molecules to produce chloride ions, smaller organic molecules, carbon dioxide, and water. Effluent from the UV-OX system passes through two GAC filters arranged in series, which remove residual organics that may still be present in the groundwater. Effluent from the GAC residual organics are neutralized, if necessary, in a second-stage neutralization tank prior to storage in two effluent tanks and discharge to the Gunpowder River. Sodium metabisulfite can also be fed to the second-stage neutralization tank to remove residual hydrogen peroxide.

2.5 Ventilatory Biomonitoring System

An in-line automated fish ventilatory biomonitoring system has been installed to monitor the final effluent as it is discharged to the Gunpowder River for any signs of acute toxicity that may result from inadequately treated groundwater (Shedd et al., 1995). The system is used as an early warning indicator of water quality conditions that may possibly exceed maximum acceptable discharge limits set by state and federal law. The system continually monitors the ventilatory and body movement patterns of fish. Stress in the form of changes in ventilatory and movement patterns is used to identify developing acute toxicity of the effluent.

The ventilatory biomonitoring system is monitored in the GWTF control room. If 6 test fish begin to show out of control responses, the biomonitoring system automatically takes an effluent sample and an investigation is initiated to determine possible causes of the response. The investigation includes one or more of the following investigative or remedial measures: 1) perform a chemical consistency analysis for site-specific parameters; 2) check typical water quality parameters; and/or 3) adjust treatment processes to eliminate the response if the response is due to water quality excursions outside required discharge limits.

In the event that the fish in the biomonitoring system exhibit stress, two tanks have been provided to store the effluent. A recycle line back to the influent equalization tanks and intermediate holding tanks allow stored effluent to be retreated if treatment has been found to be inadequate. The discharge of effluent is stopped in the event that four of eight test fish die.

SECTION 3

MATERIALS AND METHODS

3.1 General

The following is a brief overview of the ventilatory biomonitoring system. Specific details follow. The ventilatory biomonitoring system is located in the Old O-Field GWTF biomonitoring facility. A side-stream of ≈3.8 L/min (1 gpm) (Shedd, 1995) of treated effluent is supplied via a CPVC supply line from the GWTF effluent storage tanks to the biomonitoring facility (Fig. 3-1a). The resident time from the effluent storage tanks to the biomonitoring facility is ≈20 min. Control water is supplied from a 30,280 L (8,000 gal) tank located adjacent to the biomonitoring facility (Fig. 3-1b). The transient distance from the supply tank (3.2 cm line; 1.25") to the biomonitoring system is ≈ 6.1 m (≈20 ft). Potable water from various sources is used as the control water. The control water is pressurized (hydropneumatic tank) and subsequently particle-filtered, de-chlorinated via activated carbon, and aerated in two 662 L (175 gal) polyethylene aeration tanks placed in series before use in the ventilatory system (Fig. 3-1b). All materials in the ventilatory biomonitoring system consist of PVC, CPVC, and stainless steel.

The control water is temperature adjusted to 25 ± 2°C in the aeration tanks before it is supplied to the biomonitoring system proportional diluters (see below). The effluent is also adjusted to 25 ± 2°C via counter heat exchange in the downstream aeration tank before it enters the diluters. On March 1, 1996, temperatures were switched from 25 ± 2°C to 23 ± 2°C for the duration of the report period. A side stream of effluent (2 L/min) and control water (1 L/min) is passed through a Hydrolab® water quality monitor (Model Scout® v. 1.2; H20 v. 1.02; or H20 v. 2.2; Hydrolab Corp., Austin, TX) which measures temperature, pH, dissolved oxygen (DO), and conductivity at 30-min intervals. The side stream fed to the Hydrolab® alternates at 30-min intervals continuously over a 24-h period between effluent and control water by solenoids controlled via USABRDL's Aquatic Biomonitoring Program (USABRDL, 1994). The water quality measurement signals, which are acquired one time at the end of each 30-min interval for both the effluent and control water, are transduced to a ventilatory biomonitoring data acquisition system (see below). The SOPs which contain the technical specifications of the ventilatory biomonitoring system components are given in Shedd et al. (1995).

Proportional diluters are used to deliver the effluent and control water at a rate of 50 mL/min to each ventilatory chamber housing a fish. As described below, eight bluegills (Lepomis

macrochirus) are simultaneously exposed to effluent (test fish); an additional eight bluegills are also simultaneously exposed to control water (control fish). Effluent is continually supplied 24 h/day to the effluent-exposed fish by a re-circulating loop from the GWTF effluent storage tanks.

Fish ventilatory (ventilation rate, depth, and coughing frequency) and body movement signals are continually detected by opposing stainless steel electrodes placed in each ventilatory chamber. The signals are amplified, filtered, and then, as shown in Figure 3, are transduced to a DOS-based computer system which runs USABRDL's Aquatic Biomonitoring Program (USABRDL, 1994) (Fig. 3-1c). If the Aquatic Biomonitoring Program detects an out of control response (Sect. 3.2), the program activates a refrigerated ISCO® sampler (Model No. 2700R; ISCO®, Inc., Lincoln, NE) to take an effluent sample and an investigation is initiated to determine possible causes of the response as described in Section 2.5.

3.2 Biomonitoring Procedures

A test group and control group (8 fish/group) are placed in individual ventilatory chambers seven days prior to effluent exposure. The test group and control group are supplied by separate proportional diluters. The two groups are placed in the system seven days prior to the termination of a test and control group which are currently on-line. The seven-day pre-exposure period allows the fish to acclimate to the ventilatory chambers before they are used to monitor effluent.

The first eight hours of the seven-day pre-exposure period are used to determine the suitability of each fish as a test or control organism. Ventilatory and body movement signals of each fish are evaluated using the Aquatic Biomonitoring Program. The signals of each fish are observed (via an oscilloscope) during the initial eight-hour suitability period. The ventilatory rate of each fish must be between 20-100 respirations/min. Total body movement must be 50% or less to be acceptable. If a bluegill does not meet these criteria, the fish is euthanized and a new fish is placed in the system. Fish are not replaced after the first eight hours of acclimation.

Beginning on the fourth day of the seven-day pre-exposure period, the Aquatic Biomonitoring Program initiates the collection of continuous baseline ventilation and body movement data for four days. The signals for each ventilatory parameter and body movement, which are recorded and stored by the Aquatic Biomonitoring Program at 15-sec intervals, are averaged in 15-min blocks of time for statistical analysis. On day 7 of the pre-exposure period, a decision is made to accept or reject each fish for the effluent exposure phase of the ventilatory test. The acceptability criterion is based on percent body movement during

the four days of baseline recordings. Fish are rejected for use in the effluent exposure phase if total body movement occurs >50% of the time during the four-day baseline acclimation period. A minimum of six fish are needed to conduct the effluent monitoring exposure phase.

Monitoring of the GWTF effluent is initiated on day 7. One bank of eight fish is randomly selected to receive effluent. The second group of eight bluegills remains in control water. Starting November 16, 1995, conductivity had to be adjusted for the pre-exposure group scheduled to be exposed to effluent (Sect. 4.1). As a consequence, the selection of a bank of eight fish for exposure to either control or effluent was not random beginning November 16, 1995. All fish are monitored by the Aquatic Biomonitoring Program at the same frequency described above during the exposure phase to effluent and control water. The ventilatory and body movement responses of each fish during the exposure phase are compared to their own pre-exposure responses. The 15-min averages of the ventilatory and body movement data as well as the results of the statistical analyses can be observed via a monitor at the data acquisition system and/or a monitor in the GWTF control room. In addition, the signals can also be monitored off-site via a dial-up network server.

If a ventilatory or body movement parameter of an individual fish begins to respond in a manner that is statistically different from it's normal pre-exposure response, such an event is called an "out of control" response. When six or more effluent fish respond out of control, a water sample is taken by the ISCO® sampler and an investigation is initiated to determine possible causes of the out of control group response. No additional ISCO® effluent samples are taken until another out of control response occurs. Thus, if a group of fish goes out of control and stays out of control for 45 min, only one sample is taken. The out of control group must go back to normal for one 15-min interval and subsequently go out of control a second time for a second ISCO® effluent sample to be taken. A water sample is not taken by the ISCO® sampler if control fish go out of control; however, an investigation is initiated to determine possible causes of the out of control responses.

The scheduled duration of the effluent exposure period is a minimum of one week; the maximum is two weeks. The discharge of effluent to the Gunpowder River is terminated if four or more effluent fish are "redline". A fish is considered "redline" if <9 respirations/min occur. Auxiliary procedures are implemented when a group of four or more effluent-exposed fish are "redline" and subsequently die during the one or two week effluent monitoring period. Under auxiliary conditions, eight bluegills that have not received seven days of pre-exposure baseline acclimation are placed on-line to monitor the effluent for

conditions that may cause mortality. Thus, the aquatic biomonitoring system is used in the auxiliary operating mode as a mortality monitor only.

Upon completion of a one or two week exposure to effluent, all data are transferred from the data acquisition system hard drives to a transferable media and returned to USABRDL. The bluegills from the effluent and control groups are euthanized so that morphometric measurements (standard length and wet weight) can be taken. The diluter system is cleaned and calibrated at the end of each test. Sixteen new fish are added one week later, and a seven-day pre-exposure period is started.

All diluter cycle times (60 ± 5 sec) are checked daily while a test is running. The Hydrolab® is normally calibrated at the end of a test because system data cannot be logged during calibration. The photoperiod during the baseline and effluent exposure periods is continuous 24 h/day. The light intensity at the ventilatory chambers ranges from 34 to 46 foot candles. The fish are not fed during either the baseline or monitoring period.

3.3 Effluent and Control Water Quality

Water quality is measured during the effluent exposure periods as follows. The side stream Hydrolab® system measures temperature, pH, DO, and conductivity at 30-min intervals. As discussed above in Section 3.1, the side stream fed to the Hydrolab® alternates at 30-min intervals continuously over a 24-h period between effluent and control water during the exposure phase of a test. Thus, the effluent and control water parameters are sampled once per hour. All data are logged in the Aquatic Ventilatory Program data acquisition system.

Manual water quality measurements are made daily. The methods used for the analyses follow the procedures given in Shedd et al. (1995). Temperature, pH, DO, and conductivity measurements are taken once per day Monday through Friday. Hardness, alkalinity, and ammonia-nitrogen measurements are taken once each week. The hardness and alkalinity measurements were initiated July 21, 1995; ammonia-nitrogen measurements were initiated September 22, 1995. Grab samples of effluent and control water are taken from the appropriate diluters (top diluter box) before the fluids enter the fish ventilatory chamber holding boxes.

An effluent sample (300 mL) is taken by the ISCO® sampler when an out of control response occurs. Manual pH and conductivity measurements are taken. A 49 mL aliquot is preserved with 1 mL of metal grade nitric acid. As discussed above, the sample is sent to USABRDL for trace element analysis if the out of control response appears to be related to water quality excursions. The trace elements are analyzed at USABRDL

via inductively coupled plasma procedures (U.S. EPA, 1991a; 1991b).

Comprehensive chemical analyses of the effluent are performed two times per month (24-h composite samples) by the GWTF as part of their discharge compliance requirements. The analyses include metals, total suspended solids, turbidity, pH, DO, volatile organic compounds, and CSM decomposition products (thiodiglycol, 1,4-dithiane, and 1,4-oxathiane). In addition, one radiation analysis (gamma, gross alpha, and gross beta) is conducted once each quarter.

3.4 Bluegill Pre-test Holding Conditions

All bluegills used in the biomonitoring system are obtained by USABRDL from local sources. Newly acquired fish are quarantined at USABRDL for disease observations and subsequently acclimated under routine laboratory conditions for at least 30 d before they are delivered to Old O-Field. The bluegills are held in control water at the GWTF biomonitoring facility in continuous flow water (≈100 mL/min) treated as described in Section 3.2. All fish are held in groups of 10 in 37.9 L glass aquaria (10 gal) containing ≈28 L (7.5 gal) of water.

All bluegills are normally acclimated at Old O-Field for a minimum of two weeks (25 ± 2°C from June 1995 to February 1996; 23 ± 2°C during March 1996) under a 24-h light photoperiod with intensity similar to that of the fish in the biomonitoring system. General water quality, which includes temperature, pH, DO, and conductivity, are taken once per week in all holding tanks. Hardness, alkalinity, and ammonia-nitrogen are measured once each week in one holding tank selected at random.

All fish are fed commercial trout chow four times per day, seven days per week via automated fish feeders. The bluegills are fed frozen brine shrimp (<u>Artemia</u> sp.) <u>ad</u> <u>libitum</u> for 15 min each day Monday through Friday. All tanks are cleaned daily after the frozen brine shrimp feeding. The fish used in a test are approximately the same length ± 1.3 cm (0.5") and no more than 7.6 cm (3") in total length. The fish are not fed once they are placed in the ventilatory chambers.

As stated above, newly acquired fish are normally held at USABRDL for 30 d before they are delivered to Old O-Field. In August an emergency group of new fish was taken directly to the GWTF because a shortage of fish occurred due to the loss of fish when a water tank ran out of water. The new group of fish were discovered to be disease laden after being placed on-line. The diseased fish were used to complete the exposure phase to effluent.

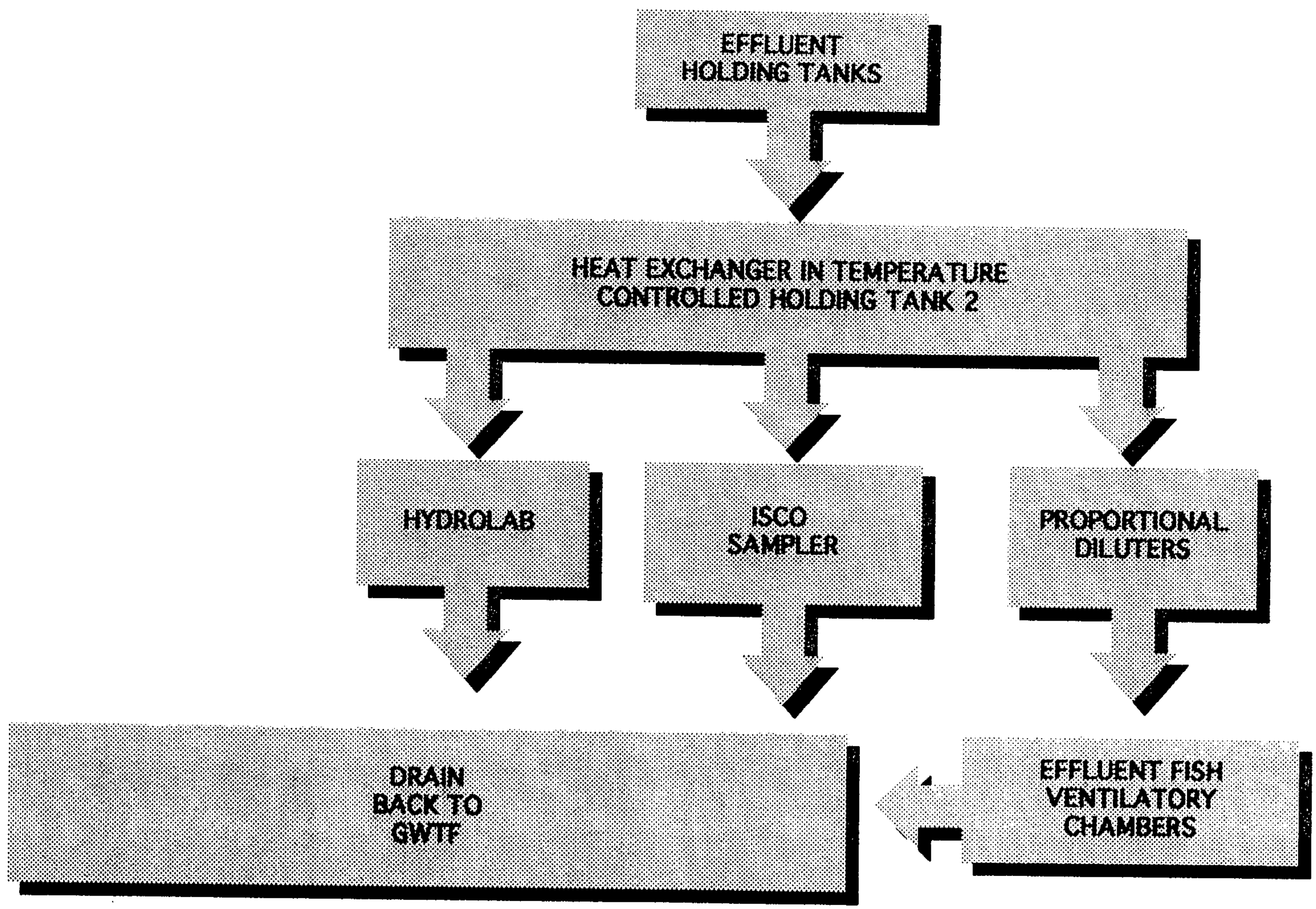

Figure 3-1a. Flow diagram of treated effluent in ventilatory biomonitoring system.

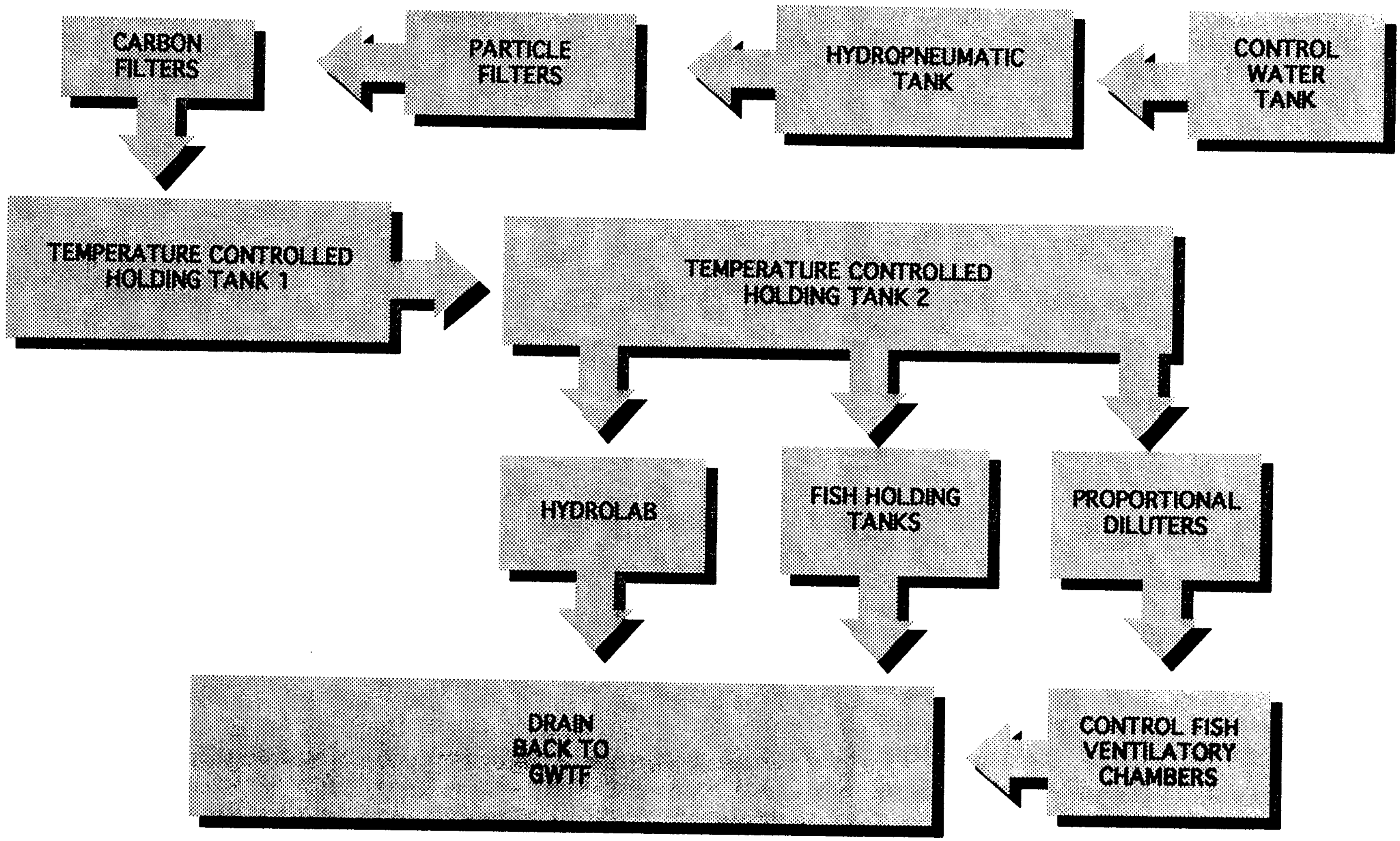

Figure 3-1b. Flow diagram of control water in ventilatory biomonitoring system.

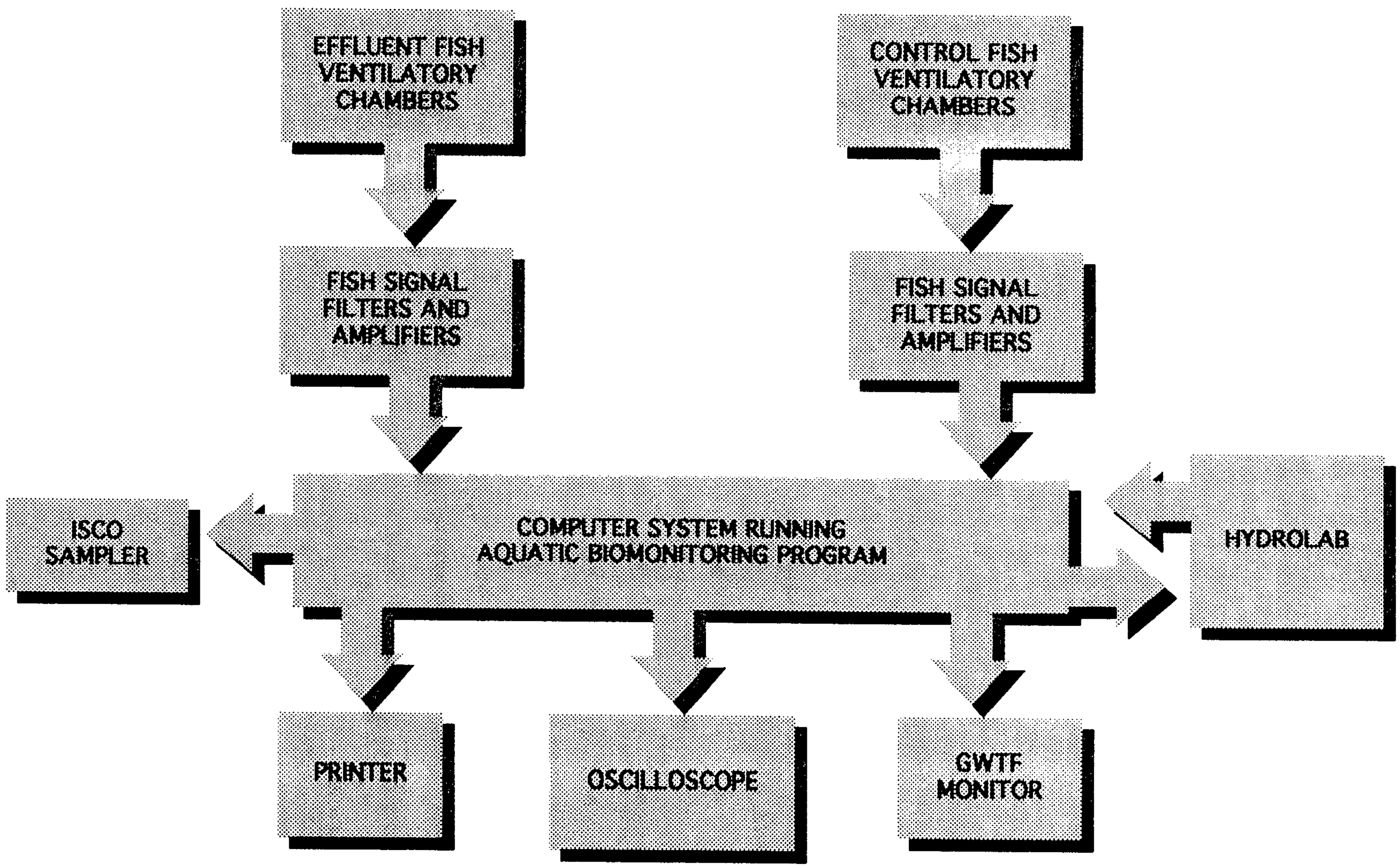

Figure 3-1c. Diagram of aquatic biomonitoring program signal paths.

SECTION 4

RESULTS AND DISCUSSION

4.1 Biomonitoring Responses

Old O-Field GWTF effluent was monitored from June 23, 1995 (14:37 h) to March 31, 1996 (24:00 h). During the period, a number of out of control events occurred which are summarized in Table 4-1a. A brief explanation is given for each response and the reason for the response when known. The out of control responses listed in Table 4-1a do not include any effluent water quality events above or below the limits under which the GWTF must operate. The monthly out of control responses for the bluegills exposed to the effluent are shown graphically in Figures 4-1a to 4-1j. The periods that effluent was discharged to the Gunpowder River are also shown in each monthly figure.

The periods when the aquatic biomonitoring system was operated as an auxiliary mortality monitor are summarized in Table 4-1b. A brief explanation is given in Table 4-1b for each period the system was operated as an auxiliary mortality monitor. No acute toxicity occurred from changes in effluent quality during the periods the system was operated as an auxiliary monitor mode. The periods when the data acquisition system was not on-line are summarized in Table 4-1c. A brief explanation is given in Table 4-1c for each period the system was not on-line.

The maximum number of days the Aquatic Biomonitoring Program could have obtained data from June 23, 1995 (14:37 h) to March 31, 1996 (24:00 h) was 282.4 d. The maximum number of 15-min blocks of data that could have been taken by the system was 27,110. The total number of days the system obtained out of control responses was 21.0 d (2,020 15-min blocks of time). Of the 21.0 d when the system obtained out of control responses, an explanation for the out of control responses was available for 20.6 d (1,973 15-min blocks of time). No obvious explanation was apparent for 0.5 d (47 15-min blocks of time). The 0.1 d discrepancy between 20.6 d and 0.5 d is due to a rounding error.

The system was operated in an auxiliary mortality monitor mode for 17.4 d (1,673 15-min blocks of time). The total amount of time the Aquatic Biomonitoring Program was not on-line was 9.5 d (911 15-min blocks of time). Approximately 4 d (≈383 15-min blocks of time) of the off-line period were scheduled; ≈5.5 d (≈528 15-min blocks of time) were due to unscheduled events.

The total percentage of time the system recorded out of control responses from June 23, 1995 to March 31, 1996 was 8.2%. The percentage was derived by dividing the total number of out of control 15-min periods (2,020) by the maximum number of 15-min

periods the system could have been in operation (27,110) less the auxiliary mortality monitor periods (1,673) and the off-line periods (911). The percentage of time the system obtained out of control responses with explanation was 8.0% (1,973/24,526). The system recorded out of control responses 0.2% of the time (47/24,526) with no readily apparent explanation.

The out of control responses with explanations occurred from one of the following three reasons (Table 4-1a): 1) changes in effluent water quality; 2) power failures; or 3) a proportional diluter failure. Changes in effluent water quality accounted for 89.2% (1,760/1,973) or 18.3 d of the total out of control responses with explanation. Loss of power and a diluter malfunction accounted for 5.9% (117/1,973) and 4.9% (96/1,973) of the out of control responses with explanation, respectively.

The largest out of control effluent water quality event was the result of an increase in effluent conductivity (relative to the conductivity of the control water) which occurred November 3-17, 1995 (Shedd, 1996a). A minor increase in conductivity event may have occurred July 31-August 1, 1995. The high effluent conductivity events accounted for 71.2% (1,274/1,760) or 13.3 d of the out of control water quality events. The average conductivity of the effluent during June, July, and August was <1,000 μmhos/cm (Sect. 4.2). The mean effluent conductivity began to increase above 1,000 μmhos/cm in September (mean = 1,060 μmhos/cm) and October (mean = 1,226 μmhos/cm). During the two weeks preceding the November event, the conductivity was running approximately 1,200-1,400 μmhos/cm. During the high conductivity event in November, the conductivity ranged between 1,400 and 1,600 μmhos/cm.

The high conductivity out of control response problem was corrected by conditioning the pre-exposure baseline effluent fish to conductivities approximating that of the effluent. A pump was installed on November 16, 1995 to supply Instant Ocean® (Aquarium Systems, Mentor, OH) to the pre-exposure baseline effluent fish only. The use of Instant Ocean® has been continuous since November 16, 1995. A solution of 120 g/L of Instant Ocean® is added from a stock source at a rate of 1.2 to 2.0 mL per diluter cycle (60 ± 5 sec/diluter cycle). The concentrated solutions of 1.2 to 2.0 mL are added to 400 mL of control water at each diluter cycle. The addition of Instant Ocean® is discontinued when the baseline fish are switched to effluent. Before the addition of Instant Ocean® on November 16, 1995, the conductivity of the control water supplied to the pre-exposure baseline effluent fish from June to October averaged ≈230 μmhos/cm.

The second largest water quality factor which caused out of control responses was a combination of dissolved oxygen shifts in conjunction with rapid changes in temperature which occurred from March 27-31, 1996 (Shedd, 1996a). The sporadic changes in DO in

combination with rapid changes in temperature accounted for 14.5% (255/1,760) or 2.7 d of the out of control responses related to changes in effluent water quality. It is not clear to the authors how the problem can be resolved so that future occurrences do not occur.

The third largest water quality factor which caused out of control responses was related to fish exposed to effluent with shortened pre-exposure baselines (baseline acclimation shortened from 4 to 1 d) which, according to Shedd (1996a), increased the fish's sensitivity to temperature stress. The short baseline with temperature stress out of control response occurred intermittently from November 17, 1995 to December 1, 1995. The event accounted for 4.8% (85/1,760) or ≈0.9 d of the out of control responses related to changes in effluent water quality. As was the case for the out of control events caused by the combination of dissolved oxygen and rapid temperature shifts, it is not clear how the problem can be resolved so that future occurrences do not occur.

A sudden drop in effluent temperature during the period February 23-26, 1996 caused a series of out of control responses (0.4 d). The event accounted for 4.1% (73-1.760) or ≈0.8 d of the out of control responses related to changes in effluent water quality. A drop in effluent temperature occurred because the return line on the downstream aeration tank (temperature control holding tank 2; Fig. 3-1b) was not secured and the water in the tank was passed to the drain rather than being recirculated. As a consequence, no control water was available ≈2 d. Thus, the tank heating units could not maintain the temperature in the effluent counter heat exchanger.

Shifts in water quality when fish were switched from control water to effluent or in some cases when fish were switched from effluent to control water caused a few out of control responses. The total out of control response time for changes in water quality was 3.2% (56/1,760) or 0.6 d. The out of control events usually lasted for periods of <2 h. On one occasion (July 28, 1995), fish that were switched from control water to effluent stayed out of control for 5.5 h. It is not clear that the switch was the actual cause for the 5.5 h out of control period relative to all other periods which lasted <2 h. The problem of producing out of control responses during the switching of pre-exposure baseline fish (control water) to effluent was eliminated when the pre-exposure baseline effluent fish were acclimated to conductivities approximating that of the effluent.

A rapid pH shift (June 26, 1995) and dissolved oxygen concentrations >100% saturation caused the remaining out of control water quality responses (Shedd, 1996a). The rapid pH shift and DO >100% saturation events accounted for 0.8% (14/1,760) (<0.1 d) and 0.2% (3/1,760) (<0.1 d) of the out of

control responses related to changes in effluent quality.

The loss of power was the second of three groups of events which caused out of control responses with explanations. Sustained losses of power occurred because 1) the GWTF backup generator did not start; 2) the backup generator ran out of fuel; and/or 3) power to the biomonitoring facility was interrupted. Fish were stressed (out of control response) and/or killed during a loss of power event because the effluent and/or control water pumps could not deliver effluent and/or control water to the fish. Relative to the water quality problems which ran for ≈18.3 d, the total time of all the power failure events was ≈1.2 d. A power outage on July 1, 1995, in which the generator started but ran out of fuel, killed the effluent-exposed fish. Control fish were switched to effluent. A power outage on July 21, 1995, killed both the effluent and control fish. Thus, fish with no pre-exposure baseline acclimation were exposed to effluent as an auxiliary mortality monitor until July 28, 1995 (Table 4-1b).

The failure of one of the proportional diluters on August 1, 1995, caused an out of control response which ran for ≈1.0 d. All effluent fish were killed when the diluter malfunctioned. During this period, fish with no pre-exposure baseline acclimation had to be used as an auxiliary mortality monitor (Table 4-1b) because no pre-exposure baseline control fish were available. The pre-exposure baseline control fish were killed on July 30, 1995 because the water tank ran out of water (Table 4-1a).

A few out of control responses occurred which did not have an apparent explanation. Out of control responses with no explanation occurred 0.2% of the time (47/24,526) or 0.5 d during the period June 23, 1995 to March 31, 1996. A total of 16 events occurred. Twelve of the 16 events lasted 1 h of less. Three of the four events >1 h lasted 1.25 h; the fourth had a duration of 1.75 h. Five of the 16 out of control events occurred during the hours of 08:00 to 17:00 h. The remaining 11 occurred between the hours of 17:01 to 07:59 h.

4.2 Effluent and Control Water Quality

This section is subdivided into the following five sections: 1) Hydrolab® effluent water quality measurements; 2) manual effluent water quality measurements; 3) Hydrolab® control water quality measurements; 4) manual control water quality measurements; and 5) ISCO® samples of out of control response trace element analyses of the effluent.

As discussed in Section 3.3, comprehensive chemical analyses of the effluent are performed by the GWTF as part of their discharge compliance requirements. The GWTF also performs comprehensive chemical analyses of the influent. Monthly summaries of the results for both the influent and effluent from

June 1995 to March 1996 are given in Appendix 1, Table A1-1. The summary is included in this report to show the general characteristics of the contaminants present in the groundwater and their average concentrations after treatment in the effluent. The summary was provided by Deeny (1996). The individual sets of chemical data from June 1995 to March 1996 can be found in Weston's quarterly monitoring reports (Weston 1995b,c, and d; 1996a,b, and c). An analysis of the relationship of possible trace levels of contaminants in the effluent versus fish ventilation responses is currently being performed by USABRDL. The results of the analysis, however, are not available at the writing of this report.

4.2.1. Effluent Water Quality- Hydrolab® Measurements

The hourly GWTF effluent temperature, pH, DO, and conductivity data obtained by the Hydrolab® system are shown on a monthly basis for June 1995 to March 1996 in Figures 4-2.1a to 4-2.1t. Note that temperature, pH, and DO for each month are presented on one graph followed by conductivity on a second graph. All values, including "out of limit" and "out of compliance" values described below, are included in the figures. The raw data are not included in this report for space limitation reasons. The raw data are archived and available from USABRDL (Shedd, 1996b).

Descriptive statistical analyses (mean, S.D., etc.) of each effluent water quality variable for each month are included in Appendix 2, Tables A2-1 to A2-10. The analyses were performed on each data set after all out of limit values were eliminated. The out of control values were not used in the descriptive statistical analyses in order to eliminate bias that would have resulted from incorrect values attributable to improper Hydrolab® function (see below). The Aquatic Biomonitoring Program was set to flag all out of limit values to 1) detect shifts in water quality parameters exceeding the criteria listed below and 2) detect potential instrumentation calibration and/or other operational problems (Shedd, 1995). All values outside the following ranges are considered out of limit: temperature = 23-27°C from the period June 23, 1995 to February 29, 1996 and 21-25°C for the period March 1 to March 31, 1996; pH = 6.5-8.5 S.U.; and DO = 3-12 mg/L. No out of limit values are set for effluent conductivity in the Aquatic Biomonitoring Program.

It can be seen in Figures 4-2.1a to 4-2.1t that the values for temperature, pH, and DO (no out of limit values for conductivity) generally fell within the ranges set in the Aquatic Biomonitoring Program. However, a number of out of limit excursions did occur. The percent that each monthly measurement exceeded the out of limit value for each parameter is given in Table 4-2.1a. The largest number of excursions occurred with temperature. With the exception of June in which no temperature

excursions occurred, the out of limit excursions ranged from a low of 2% in March to a high of 46% in November. pH excursions occurred during the months of June, July, and September.

DO excursions outside the range of 3-12 mg/L occurred during the months of June, July, and August. In most of the cases, the DO values were above 12 mg/L. A number of the high readings approached an order of magnitude above saturation at 25°C. DO saturation at 25°C (atmospheric pressure = 760 mm Hg and salinity = 0 ppt) for freshwater is ≈8.2 mg/L. The excessively high values indicate that the oxygen sensor in the Hydrolab® system had 1) a recurring operational problem or 2) some material(s) present in the effluent may have interfered with the normal functioning of the probe. On several occasions when the high values occurred, air bubbles were observed under the oxygen sensor membrane. Several DO readings below 3 mg/L occurred at the end of July and the first week of August. The low readings July 31 and early August 1 may be related to excess metabisulfite added to the treatment process (Fig. 4-2.1c and e). The low DO combined with a diluter malfunction (loss of effluent flow) subsequently killed all effluent-exposed fish on August 1, 1995.

No out of control values were set in the Aquatic Biomonitoring Program for effluent conductivity. However, the measurements for June 23 to July 8 were "odd" (Fig. 4-2.1b and 4-2.1d). That is, the values oscillated between a low of ≈200-500 μmhos/cm to a high of ≈600-1,100 μmhos/cm. In general, conductivity was rather variable during the period June to August. As discussed in Section 4.1, conductivity increased for several months from August through November. Conductivity was also variable during the months of January through March (Fig. 4-2.1p, 4-2.1r, and 4-2.1t). Conductivity varied in January, February, and March from 420-1,126, 620-1,019 (Note: values <10, which were due to no water in the Hydrolab® cell, were omitted), and 676-1,013 μmhos/cm, respectively.

The GWTF has a number of physical and chemical effluent parameters that must be within certain bounds for regulatory compliance purposes (Sect. 3.3). The following three parameters, which are monitored by the Hydrolab® system, must be within the bounds shown: temperature cannot exceed 32.2°C (90°F); pH must fall between 6.5 and 8.5 S.U.; and DO cannot be <5.0 mg/L. There is no discharge compliance requirement for conductivity. Although the Hydrolab® system monitors temperature, the Hydrolab® temperature data cannot be used for compliance monitoring because the temperature of the effluent was adjusted to 25 ±2°C from June 27, 1995 to February 29, 1996 and 23 ±2°C from March 1 through March 31, 1996 (Sect. 3.1). As stated above, temperatures did not always fall within the ranges of 25 ±2°C or 23 ±2°C.

pH fell within the compliance bounds for all months except June, July, and September (Table 4-2.1b). The percent of pH

readings that the monthly pH measurements exceeded the out of compliance values for June, July, and September were 8%, 13%, and 11%, respectively.

Dissolved oxygen had the largest number of out of compliance excursions. With the exception of November in which DO was never <5.0 mg/L, the out of compliance excursions ranged from a low of 1% in October to a high of 31% in August. As was the case for the high DO values discussed above, the low Hydrolab® values may also be related to 1) a recurring operational problem or 2) some material(s) present in the effluent may have interfered with the normal functioning of the probe. Indeed, the daily manual DO readings discussed below in Section 4.2.2 indicate that the Hydrolab® values may not be accurate in several cases. The daily manual DO measurements showed that DO was above 5 mg/L for all months except one reading in August, one reading in September, and five readings in March. Shedd (1996a) conducted an analysis of the manual and Hydrolab® DO readings of the effluent taken within one hour of each other. He found that the majority of the manual DO readings were higher than the Hydrolab® readings by an average of 0.35 mg/L. A similar analysis of the control water showed that the manual readings were higher than the Hydrolab® readings by an average of 0.34 mg/L (Shedd, 1996a).

4.2.2 Effluent Water Quality- Manual Measurements

The daily GWTF effluent temperature, pH, DO, conductivity, alkalinity, and hardness data obtained manually are shown on a monthly basis for June 1995 to March 1996 in Figures 4-2.2a to 4-2.2t. Temperature, pH, and DO for each month are presented on one graph followed by conductivity, alkalinity, and hardness on a second graph. Alkalinity and hardness measurements were not started until July 21, 1995; therefore, there are no alkalinity or hardness values for the month of June. Ammonia-nitrogen measurements were initiated September 22, 1995. Only one value >0.26 mg/L NH_3-N was found between September 22, 1995 and March 31, 1996; 0.39 mg/L NH_3-N occurred on January 3. Therefore, ammonia-nitrogen values are not presented graphically.

Descriptive statistical analyses of each effluent water quality variable for each month are included in Appendix 3, Tables A3-1 to A3-10. The analyses were performed on all data including any out of limit values described below. In contrast to the questionable out of control Hydrolab® values not used in Section 4.2.1., all manual out of control values were used because no instrumentation problems occurred.

The daily manual values for temperature, pH, DO, and conductivity (Figures 4-2.2a to 4-2.2t) all fell within the ranges measured by the Hydrolab® system. With regard to temperature, the manual measurements showed that effluent temperatures fell within 25 ± 2°C from June to August (Sect.

3.1). Starting in September, temperature excursions below 23°C occurred in all months through February (Appendix 3, Tables A3-1 to A3-10). All temperature readings fell within 23 ± 2°C in March. One pH reading below 6.5 occurred in August; one pH reading above 8.5 was found in September. DO was above 5 mg/L for all months except one reading in August; one reading in September; and five readings in March.

As observed with the Hydrolab® system, manual measurements of conductivity were rather variable from June to August. Conductivity increased for several months from September to November. The low Hydrolab® conductivity values that ranged from ≈200-500 μmhos/cm during the "odd" low and high value period described in Section 4.2.2 for June 23 to July 8 were not observed in the manual measurements. This suggests that the Hydrolab® probe was not functioning properly. Sporadic low values were recorded by the Hydrolab® in February (Fig. 4-2.1r) which were not observed in the manual readings (Fig. 4-2.2r). According to Shedd (1996a), no effluent was present in the Hydrolab® probe chamber during these periods due to a mechanical failure of the water delivery system to the Hydrolab®.

4.2.3 Control Water Quality- Hydrolab® Measurements

The hourly control water temperature, pH, DO, and conductivity data obtained by the Hydrolab® system are shown on a monthly basis for June 1995 to March 1996 in Figures 4-2.3a to 4-2.3t. As in the graph format for Section 4.2.1, temperature, pH, and DO for each month are presented on one graph followed by conductivity on a second graph. All values, including out of limit values described in Section 4.2.1 for temperature, pH, and DO are included in the figures. In contrast to effluent which had no out of limit values for conductivity, out of limit values of 100-1,000 μmhos/cm for conductivity were flagged by the Aquatic Biomonitoring Program.

The GWTF does not have any out of compliance requirements for the control water; therefore, "out of compliance" data are not discussed. The raw data are not included in this report but are available from USABRDL (Shedd, 1996b). The descriptive statistical analyses of the control water quality variables for each month are included in Appendix 4, Tables A4-1 to A4-10. The analyses were performed on each data set after all out of limit values were eliminated. All values outside the following ranges are considered out of limit: temperature = 23-27°C from June 23, 1995 to February 29, 1996 and 21-25°C from March 1 to March 31, 1996; pH = 6.5-8.5 S.U.; DO = 3-12 mg/L; and conductivity = 100-1,000 μmhos/cm.

The values for temperature, pH, DO, and conductivity generally fell within the ranges set in the Aquatic Biomonitoring Program. As was the case for the effluent, a number of out of

limit excursions did occur for temperature. The percent of each monthly measurements that exceeded the out of limit value for temperature is given in Table 4-2.3a. No temperature excursions occurred during the months of June and October. The out of limit excursions for the remaining eight months ranged from a low of 2% in January and March to a high of 15% in August. Out of limit excursions also occurred for pH in February and March, DO in July and August, and conductivity in June and February (Table 4-2.3a).

pH values above 8.5 occurred in February and March immediately after the lost of control water from February 24-26 when the return line on the downstream aeration tank was not secured and no control water was available for ≈2 days (Sect. 4.1). The loss of water apparently affected the calibration of the Hydrolab® probe.

DO excursions outside the range of 3-12 mg/L occurred during the months of July and August. A number of DO values approached concentrations almost an order of magnitude above saturation at 25°C during the same periods the events occurred in the effluent. The excessively high values indicate that 1) the oxygen sensor in the Hydrolab® system had a recurring operational problem or 2) some material(s) present in the effluent may have interfered with the normal functioning of the probe which also caused aberrant readings in the control water. Air bubbles were observed under the oxygen sensor membrane on several occasions when the high values occurred.

Conductivity out of control excursions occurred during the months of June and February. Approximately 12% of the readings were <100 μmhos/cm in June; approximately 5% were <100 μmhos/cm in February. As was the case for effluent, the measurements for June 23 to July 8 were "odd" (Fig 4-2.3b and 4-2.3d). That is, the values oscillated between two sets of values. Conductivity also oscillated from an average of ≈200 μmhos/cm up to ≈800 μmhos/cm from July 30 to July 31 and from August 3 and August 4. A spike from control water values to values similar to that of the effluent occurred November 13, 1995 and February 2-3, 1996. No obvious explanation, other than possible conductivity probe malfunction, is available for the temporary excursions. The out of control excursions that occurred February 24-25 are the result of a loss of water flow when the return line on the downstream aeration tank was not secured; no control water was available for ≈2 days (Sect. 4.1).

4.2.4 Control Water Quality- Manual Measurements

The daily GWTF control water temperature, pH, DO, conductivity, alkalinity, and hardness data obtained manually are shown on a monthly basis for June 1995 to March 1996 in Figures 4-2.4a to 4-2.4t. As in the previous graphs, temperature, pH, and DO for each month are presented on one graph followed by

conductivity, alkalinity, and hardness on a second graph. No alkalinity or hardness values for the month of June 1995 are included on the graph because alkalinity and hardness measurements were not started until July 21, 1995. Ammonia-nitrogen measurements were initiated September 22, 1995; however, all values were ≤0.026 mg/L NH_3-N. Thus, no ammonia-nitrogen values are presented graphically. The raw data are not included in this report but are available from USABRDL (Shedd, 1996b). The descriptive statistical analyses of all control water quality parameters for each month are included in Appendix 5, Tables A5-1 to A5-10. The analyses were performed on all data including any out of limit values.

The daily values for temperature, pH, DO, and conductivity (Figures 4-2.4a to 4-2.4t) were consistent from month to month. With regard to temperature, the manual measurements showed that the majority of control water temperature values fell within the temperature limits of 25 ± 2°C (June 27, 1997 to February 29, 1996) and 23 ± 2°C (March 1 to March 31, 1996). Only one value in July (27.4°C) and November (27.2°C) exceeded 27°C. Similarly, only one value occurred below 23°C in September (22.6°C), October (22.9°C), and February (22.8°C). All but two of the manual pH readings fell within the range of 6.5 to 8.5. A value of 8.6 occurred in July and a reading of 6.0 was observed in August. All DO measurements were above 5 mg/L.

Conductivity was constant from June through March relative to the effluent. The monthly means ranged from a low of 206.4 µmhos/cm in August to a high of 273.9 µmhos/cm in November (Appendix 5, Tables A5-3 and A5-6). The low values that averaged ≈150 µmhos/cm during the "odd" split conductivity event described in Section 4.2.3 for June 23 to July 8 for the Hydrolab® system were not present in the manual measurements. This suggests that the Hydrolab® probe was not functioning properly. Likewise, the spikes in conductivity described in Section 4.2.3 were not observed in the manual measurements.

4.2.5 ISCO® Out of Control Response Sample Measurements

As discussed in Section 3.2, if the Aquatic Biomonitoring Program detects an out of control response, the program activates a refrigerated ISCO® sampler to take an effluent sample and an investigation is initiated to determine possible causes of the response. The preserved sample is sent to USABRDL for metal analysis if the out of control response appears to be related to a possible water quality excursion.

A number of effluent samples, which are summarized in Table A6-1 of Appendix 6, were analyzed for trace metals by USABRDL during the period June 23, 1995 to March 31, 1996. An analysis of the relationship of metal concentrations versus fish ventilation responses is currently being performed by USABRDL.

The results of the analysis, however, are not available at the writing of this report. The manual pH and conductivity measurements taken on the ISCO® samples before they were preserved for trace element analyses did not detect any values outside the range observed for the daily manual samples taken in the same month (Shedd, 1996a).

4.3 Fish Morphometries

All bluegills used in the aquatic biomonitoring system were held in most cases for a minimum of two weeks in control water at the GWTF biomonitoring facility as described in Section 3.4. The general water quality during acclimation, which included temperature, pH, DO, conductivity, alkalinity, hardness, and ammonia-nitrogen, fell within the limits discussed above for the manual control water measurements (Sect. 4.2.4). The raw data are not included in this report but are available from USABRDL (Shedd, 1996b).

Bluegills exposed to GWTF effluent and control water were weighed (wet weight) and measured (standard length) at the end of each weekly or biweekly test. The mean (± S.D.) wet weight and standard length of all bluegills (n = 344) exposed to both GWTF effluent and control water during the period June 23, 1995 to March 31, 1996 were 5.0 (± 2.68; range = 0.8-15.2) g and 55.0 (± 9.01; range = 33.0-76.0) mm, respectively. The wet weight and standard length of each fish are shown graphically in Figures 4-3a and 4-3b.

Condition factors are frequently used as indicators of the relative quality of a fish population. Since the bluegills were not fed after being placed in the ventilatory chambers, relative weight (a standard fishery condition factor metric) was examined to determine the quality of the fish relative to bluegills in wild populations. A wild bluegill population with a mean standard length of 55 mm has a standard wet weight of 2.9 g (Swingle and Shell, 1971). Relative weight is determined by dividing a fish's actual wet weight by standard wet weight (based on standard length) and multiplying the quotient by 100.

The relative weight of the bluegills used from June 23, 1995 to March 31, 1996 were calculated and graphed (Fig. 4-3c). With the exception of two fish, all bluegills were above the relative weight for fish of their length (Moehl and Davies, 1993). Thus, the lack of food during seven days of baseline acclimation and the additional 7-14 days during exposure did not affect the relative weight condition factor when compared to a wild population of bluegills. More importantly, Swingle and Shell (1971) have shown that relative fish condition may be useful in detecting prolonged physiological stress in a fish population. The relative weight data indicate that the quality of the effluent was not particularly stressful to bluegills.

TABLE 4-1A. OUT OF CONTROL RESPONSES AND BRIEF EXPLANATIONS[a]

DATE	OUT OF CONTROL STARTING TIME	OUT OF CONTROL ENDING TIME	PERIODS OF DISCHARGE	EXPLANATION
26-Jun	13:52	17:22	09:00-16:30	Rapid pH shift.
30-Jun	09:07	10:22	07:30-12:00	Power loss from 08:42-09:25 h; backup generator did not start.
1-Jul	03:52	24:00	NONE	Power loss; backup generator operated until it ran out of fuel. No estimation of time when generator stopped.
2-Jul	00:00	07:30	07:20-24:00	Effluent fish dead due to power outage on 1-Jul. Control fish were switched to effluent on 2-Jul at approximately 07:30 h.
21-Jul	06:15	06:45	NONE	Power loss at 05:50 h; power restored at 09:36 h. Power outage caused loss of effluent and control fish. At 14:20 h fish with no 7-day pre-exposure baseline acclimation were exposed to effluent as an auxiliary mortality monitor until 28-Jul.
28-Jul	13:24	18:54	06:30-13:25	At 12:51 h fish were switched from control water to effluent (i.e., fish were placed on-line). Differences in water quality between control water and effluent caused response.
29-Jul	01:39 04:09 06:24	02:39 04:39 06:54	NONE	No explanation. No explanation. No explanation.
1-Aug	09:09 12:09	10:09 24:00	NONE	Low DO possibly caused by excess metabisulfite. Diluter malfunction killed all effluent fish.

TABLE 4-1A. CONTINUED

DATE	OUT OF CONTROL STARTING TIME	OUT OF CONTROL ENDING TIME	PERIODS OF DISCHARGE	EXPLANATION
2-Aug	00:00	12:09	07:00-17:00	Fish with no 7 day pre-exposure baseline acclimation were loaded into effluent chambers. Control fish were killed on 30-Jul because water tank ran out of water; thus, no control fish were available for exposure to effluent. Fish were exposed at 14:59 to effluent as an auxiliary monitor until 9-Aug.
18-Aug	08:33 13:48	10:48 14:03	NONE	At 06:50 h effluent fish were switched to control water due to "low" DO (4.9 mg/L). Differences in water quality between effluent and control water caused response. At 12:55 h a power outage occurred; backup power was not available until 13:02 h.
23-Aug	19:51	20:21	00:00-02:30 07:00-24:00	No explanation (Fish were compromised by disease).
17-Sep	18:30 19:15	18:45 19:45	13:40-21:10	DO >100% saturation. DO >100% saturation.
17-Oct	21:45	22:00	00:00-02:00 13:00-20:00	At 20:30 h effluent switched to control water due to two redline fish. Differences in water quality between effluent and control water caused response.
26-Oct	22:15	22:30	12:05-18:00 20:40-22:15	At 20:40 h GWTF started discharging effluent. At 22:15 h out of control response caused GWTF to switch effluent to control water. At 22:35 h fish switched back to effluent. It is not clear that the switching caused the out of control response.
3-Nov	13:58	24:00	00:00-02:00 09:00-10:00	New fish put on-line at approximately 13:13 h. High effluent conductivity caused response.

TABLE 4-1A. CONTINUED

DATE	OUT OF CONTROL STARTING TIME	OUT OF CONTROL ENDING TIME	PERIODS OF DISCHARGE	EXPLANATION
4-Nov	00:00	24:00	NONE	High effluent conductivity.
5-Nov	00:00 15:42	14:27 24:00	NONE	At 13:20 h GWTF found fish out of control and switched effluent to control water at 13:45 h. At 14:43 h fish were switched back to effluent. High effluent conductivity.
6-Nov	00:00	24:00	11:00-15:00 19:00-20:00	High effluent conductivity.
7-Nov	00:00 07:57	01:12 24:00	12:00-24:00	At 00:20 h fish switched from effluent to control water because of a redline fish. Fish switched back to effluent at 07:00 h. High effluent conductivity.
8-Nov	00:00	24:00	00:00-02:00 09:00-14:00 23:00-24:00	High effluent conductivity.
9-Nov	00:00 11:43	09:57 24:00	00:00-04:00 15:00-23:00	High effluent conductivity. Data acquisition system taken off-line at 09:42 h and put back on line at 11:43 h. No data acquired during this period.
10-Nov	00:00	24:00	NONE	High effluent conductivity.
11-Nov	00:00	24:00	NONE	High effluent conductivity.
12-Nov	00:00	24:00	NONE	High effluent conductivity.
13-Nov	00:00	24:00	11:00-15:00 18:00-23:00	High effluent conductivity.
14-Nov	00:00	24:00	02:00-07:00 11:00-13:00 15:00-18:00 22:00-23:00	High effluent conductivity.
15-Nov	00:00 06:42	02:42 24:00	00:00-01:00 09:00-24:00	High effluent conductivity. High effluent conductivity.

TABLE 4-1A. CONTINUED

DATE	OUT OF CONTROL STARTING TIME	OUT OF CONTROL ENDING TIME	PERIODS OF DISCHARGE	EXPLANATION
16-Nov	00:00	13:57	00:00-02:00	High effluent conductivity.
	16:22	24:00	07:00-13:00	High effluent conductivity.
			17:00-18:00	
			21:00-24:00	
17-Nov	00:00	11:07	00:00-01:00	High effluent conductivity.
	14:24	14:54	10:00-11:00	New fish with shortened baseline (from 4 to 1 day) caused increased sensitivity to temperature stress from 17-Nov to 1-Dec. Response information during this period was not consistent with the rest of the response data.
	15:09	16:09		Short baseline with temperature stress.
18-Nov	05:54	06:39	NONE	Short baseline with temperature stress.
26-Nov	23:54	24:00	NONE	Short baseline with temperature stress.
27-Nov	00:00	00:24	09:00-15:00	Short baseline with temperature stress.
	01:39	02:54	17:00-22:00	Short baseline with temperature stress.
	03:24	04:39	09:00-15:00	Short baseline with temperature stress.
	05:54	06:09	17:00-22:00	Short baseline with temperature stress.
	06:39	06:54		Short baseline with temperature stress.
	13:39	13:54		Short baseline with temperature stress.
	16:54	17:39		Short baseline with temperature stress.
	18:54	20:09		Short baseline with temperature stress.
	20:39	20:54		Short baseline with temperature stress.
	23:54	24:00		Short baseline with temperature stress.
28-Nov	00:00	00:09	08:00-13:00	Short baseline with temperature stress.
	16:09	16:24	17:00-24:00	Short baseline with temperature stress.
30-Nov	04:39	04:54	02:00-07:00	Short baseline with temperature stress.
	07:24	07:54	17:00-24:00	Short baseline with temperature stress.
	13:54	14:09		Short baseline with temperature stress.
	14:24	14:39		Short baseline with temperature stress.
	15:54	16:24		Short baseline with temperature stress.
	21:39	23:24		Short baseline with temperature stress.

TABLE 4-1A. CONTINUED

DATE	OUT OF CONTROL STARTING TIME	OUT OF CONTROL ENDING TIME	PERIODS OF DISCHARGE	EXPLANATION
1-Dec	00:24 05:54 07:54 09:24 10:24	04:54 07:24 08:54 10:09 11:39	00:00-01:00 08:00-11:00	Short baseline with temperature stress. Short baseline with temperature stress. Short baseline with temperature stress. Short baseline with temperature stress. Short baseline with temperature stress.
11-Dec	18:31	18:46	NONE	At 14:23 h effluent switched to control water for GWTF to perform maintenance. Differences in water quality between control water and effluent caused response. Fish switched back to effluent at 21:00 h.
26-Dec	09:31 10:46	10:31 12:01	12:30-24:00	No explanation. No explanation.
28-Dec	22:16	24:00	00:00-16:00	No explanation.
29-Dec	00:00 01:46	01:16 02:31	00:00-09:00 23:00-24:00	No explanation. No explanation.
23-Jan	17:39 19:09	18:09 20:24	00:00-10:00 22:00-23:00	At 11:05 h effluent fish were switched to control water for GWTF to perform maintenance. Fish switched back to effluent at 15:40 h.
24-Jan	12:39 13:09	12:54 14:24	00:00-11:00	No explanation. No explanation.
27-Jan	05:53	06:08	NONE	No explanation.
9-Feb	12:42	14:12	00:00-09:00 15:00-23:00	At 12:42 h fish were switched from control water to effluent. Differences in water quality between control water and effluent caused response.
11-Feb	04:57	05:42	NONE	No explanation.

TABLE 4-1A. CONTINUED

DATE	OUT OF CONTROL STARTING TIME	OUT OF CONTROL ENDING TIME	PERIODS OF DISCHARGE	EXPLANATION
22-Feb	04:56	06:56	00:00-03:00 09:00-17:00	At 04:00 h effluent fish were switched to control water. Differences in water quality between control water and effluent caused response. Fish switched back to effluent at 06:05 h.
23-Feb	15:58 22:13	18:58 24:00	00:00-10:00	Low temperature stress. Low temperature stress.
24-Feb	00:00 20:13 23:13	00:28 22:58 24:00	NONE	Low temperature stress. Low temperature stress. Low temperature stress.
25-Feb	00:00 03:58 06:28 09:13 23:43	01:58 05:28 07:28 09:28 24:00	NONE	Low temperature stress. Low temperature stress. Low temperature stress. Low temperature stress. Low temperature stress.
26-Feb	00:00	00:13	22:00-24:00	Low temperature stress.
27-Feb	00:43 04:28	02:58 04:58	04:00-09:00 13:00-18:00	Low temperature stress. Low temperature stress.
28-Feb	05:58 08:13	07:13 08:28	00:00-05:00 11:35-19:00	Low temperature stress. Low temperature stress.
11-Mar	07:31 09:57 11:57	07:46 10:12 12:12	18:00-23:00	No explanation. No explanation. At 10:25 h effluent fish were switched to control water for GWTF to calibrate instruments. Fish switched back to effluent at 10:50 h.
27-Mar	06:14 08:59 15:14	07:14 10:29 24:00	00:00-09:00 14:00-24:00	DO shifts and rapid changes in temperature. DO shifts and rapid changes in temperature. DO shifts and rapid changes in temperature.

TABLE 4-1A. CONTINUED

DATE	OUT OF CONTROL STARTING TIME	OUT OF CONTROL ENDING TIME	PERIODS OF DISCHARGE	EXPLANATION
28-Mar	00:00	08:29	00:00-03:00	DO shifts and rapid changes in temperature.
	08:59	09:14	16:00-24:00	DO shifts and rapid changes in temperature.
	10:14	12:44		DO shifts and rapid changes in temperature.
	17:44	17:59		DO shifts and rapid changes in temperature.
	18:14	18:29		DO shifts and rapid changes in temperature.
	19:44	20:44		DO shifts and rapid changes in temperature.
	22:29	24:00		DO shifts and rapid changes in temperature.
29-Mar	00:00	05:29	00:00-07:00	DO shifts and rapid changes in temperature.
	05:59	07:44		DO shifts and rapid changes in temperature.
	07:59	14:44		DO shifts and rapid changes in temperature.
	16:44	17:29		DO shifts and rapid changes in temperature.
	17:59	19:59		DO shifts and rapid changes in temperature.
30-Mar	13:44	19:44	00:29-12:14	DO shifts and rapid changes in temperature.
	21:14	22:44		DO shifts and rapid changes in temperature.
	23:59	24:00		DO shifts and rapid changes in temperature.
31-Mar	00:00	00:59	23:00-24:00	DO shifts and rapid changes in temperature.
	01:44	02:44		DO shifts and rapid changes in temperature.
	03:29	04:14		DO shifts and rapid changes in temperature.
	05:14	11:14		DO shifts and rapid changes in temperature.
	14:29	16:44		DO shifts and rapid changes in temperature.
	16:59	19:59		DO shifts and rapid changes in temperature.

[a] Out of control response explanations provided by Shedd (1996a).

TABLE 4-1B. PERIODS WHEN AQUITIC BIOMONITORING SYSTEM WAS USED AS AN AUXILIARY MORTALITY MONITOR

DATE START TIME	DATE ENDING TIME	EXPLANATION
21-Jul 15:54	28-Jul 13:34	Power outage caused loss of effluent and control fish. Fish with no 7-day pre-exposure baseline acclimation were exposed to effluent.
2-Aug 14:59	9-Aug 17:06	Effluent fish were killed on 1-Aug by a diluter malfunction. Fish with no 7-day pre-exposure baseline acclimation were exposed to effluent.
13-Oct 13:45	16-Oct 18:23	Programming error disabled BLPGM program. No baseline statistics could be obtained for the on-line period.

TABLE 4-1C. PERIODS WHEN AQUATIC BIOMONITORING PROGRAM DATA ACQUISITION SYSTEM WAS NOT ON-LINE

DATE	START TIME	ENDING TIME	EXPLANATION
23-Jun		14:37	Bi-weekly calibration and data transfer.[a]
7-Jul	11:52	14:00	Weekly calibration and data transfer.[a]
21-Jul	06:30	15:54	Power outage shut program down at 06:30 h.[b] Bi-weekly calibration and data transfer.[a]
28-Jul	10:24	13:24	Weekly calibration and data transfer.[a]
2-Aug	11:54	14:59	General error occurred in data acquisition system.[b]
4-Aug	09:44	15:09	General error occurred in data acquisition system.[b]
9-Aug	12:38	17:06	New fish placed on-line; data transfer.[a]
14-Aug	13:51	17:33	Installation and calibration of another Hydrolab.[b]
21-Aug	12:45	15:06	No documentation for shut down of data acquisition system.[b]
25-Aug	10:51	15:32	Bi-weekly calibration and data transfer.[a]
1-Sep	12:23	15:53	Weekly calibration and data transfer.[a]
8-Sep	09:53	13:33	Weekly calibration and data transfer.[a]
15-Sep	11:15	16:45	Weekly calibration and data transfer.[a]
22-Sep	10:15	17:28	Weekly calibration and data transfer.[a]
29-Sep	12:13	14:37	No documentation for shut down of data acquisition system.[b]
6-Oct	10:52	15:39	Weekly calibration and data transfer.[a]
13-Oct	09:39	24:00	Weekly calibration and data transfer.[a] Program error; no data collected. System ran as auxiliary mortality monitor until 16-Oct.[b]
14-Oct	00:00	24:00	See 13-Oct explanation.[b]
15-Oct	00:00	24:00	See 13-Oct explanation.[b]
16-Oct	00:00	18:23	Program error corrected.[a]
17-Oct	10:08	12:00	Program error corrected.[a]
20-Oct	11:00	15:45	Weekly calibration and data transfer.[a]
27-Oct	10:30	14:39	Weekly calibration and data transfer.[a]
3-Nov	11:39	13:58	Weekly calibration and data transfer.[a]

TABLE 4-1C. CONTINUED

DATE	START TIME	ENDING TIME	EXPLANATION
9-Nov	09:42	11:43	Statistical programming changes made in data acquisition system.[b]
16-Nov	13:42	16:22	No documentation for shut down of data acquisition system.[b]
17-Nov	10:52	13:39	Bi-weekly calibration and data transfer.[a]
1-Dec	11:24	14:16	Bi-weekly calibration and data transfer.[a]
15-Dec	10:31	15:17	Bi-weekly calibration and data transfer.[a]
29-Dec	10:16	13:45	Bi-weekly calibration and data transfer.[a]
4-Jan	09:30	12:09	Re-calibration.[b]
12-Jan	08:24	14:46	Bi-weekly calibration and data transfer.[a]
15-Jan	09:31	13:48	Installation of water quality transmitter.[b]
17-Jan	10:48	14:24	Installation of water quality transmitter.[b]
26-Jan	09:53	12:53	Bi-weekly calibration and data transfer.[a]
9-Feb	09:38	12:42	Bi-weekly calibration and data transfer.[a]
23-Feb	09:56	15:58	Bi-weekly calibration and data transfer.[a]
29-Feb	07:13	11:06	Re-calibration.[b]
8-Mar	09:06	14:46	Bi-weekly calibration and data transfer.[a]
11-Mar	08:14 14:42	09:57 15:59	Power loss to Hydrolab.[b] Power loss to Hydrolab.[b]
22-Mar	09:13	16:44	Bi-weekly calibration and data transfer.[a]
25-Mar	11:14	12:45	Installation of water quality transmitter.[b]

[a] Scheduled event.
[b] Unscheduled event.

TABLE 4-2.1A. PERCENTAGE OF MONTHLY MEASUREMENTS EACH EFFLUENT WATER QUALITY PARAMETER EXCEEDED THE UPPER AND LOWER LIMITS SET IN THE AQUATIC BIOMONITORING PROGRAM FROM JUNE 1995 TO MARCH 1996

MONTH	TEMPERATURE	pH	DO	CONDUCTIVITY
June	0	8	6	0
July	6	13	22	0
August	8	0	7	0
September	3	11	0	0
October	6	0	0	0
November	46	0	0	0
December	26	0	0	0
January	41	0	0	0
February	23	0	0	0
March	2	0	0	0

TABLE 4-2.1B. PERCENTAGE OF MONTHLY MEASUREMENTS EACH EFFLUENT WATER QUALITY PARAMETER EXCEEDED GWTF DISCHARGE COMPLIANCE REQUIREMENTS FROM JUNE 1995 TO MARCH 1996

MONTH	TEMPERATURE	pH	DO	CONDUCTIVITY
June	0	8	10	0
July	0	13	7	0
August	0	0	31	0
September	0	11	12	0
October	0	0	1	0
November	0	0	0	0
December	0	0	20	0
January	0	0	30	0
February	0	0	20	0
March	0	0	18	0

TABLE 4-2.3A. PERCENTAGE OF MONTHLY MEASUREMENTS EACH CONTROL WATER QUALITY PARAMETER EXCEEDED THE UPPER AND LOWER LIMITS SET IN THE AQUATIC BIOMONITORING PROGRAM FROM JUNE 1995 TO MARCH 1996

MONTH	TEMPERATURE	pH	DO	CONDUCTIVITY
June	0	0	0	12
July	11	0	21	0
August	15	0	10	0
September	3	0	0	0
October	0	0	0	0
November	10	0	0	0
December	3	0	0	0
January	2	0	0	0
February	13	10	0	5
March	2	2	0	0

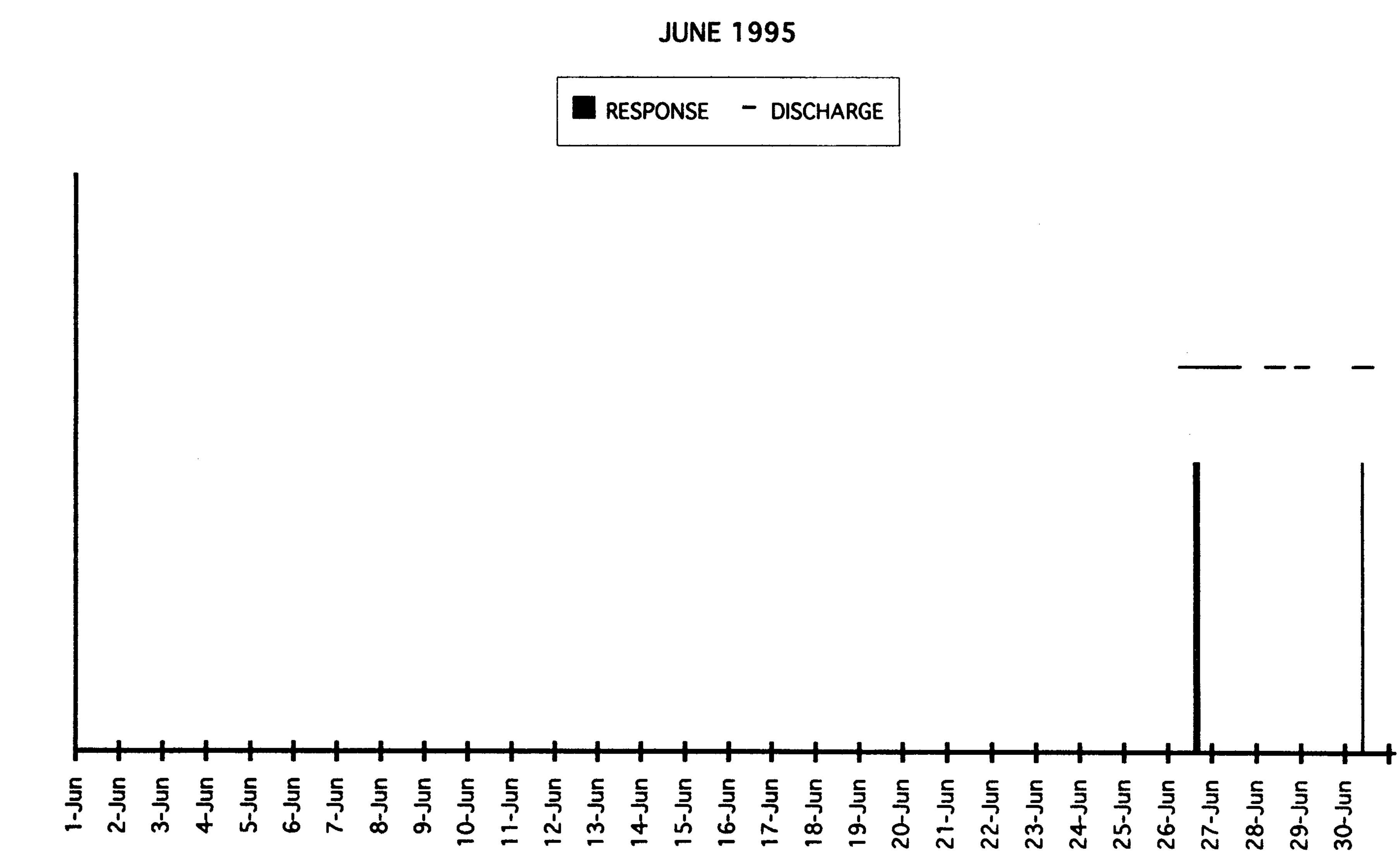

Figure 4-1a. "Out of control" responses and discharge periods of GWTF effluent to the Gunpowder River during June 1995.

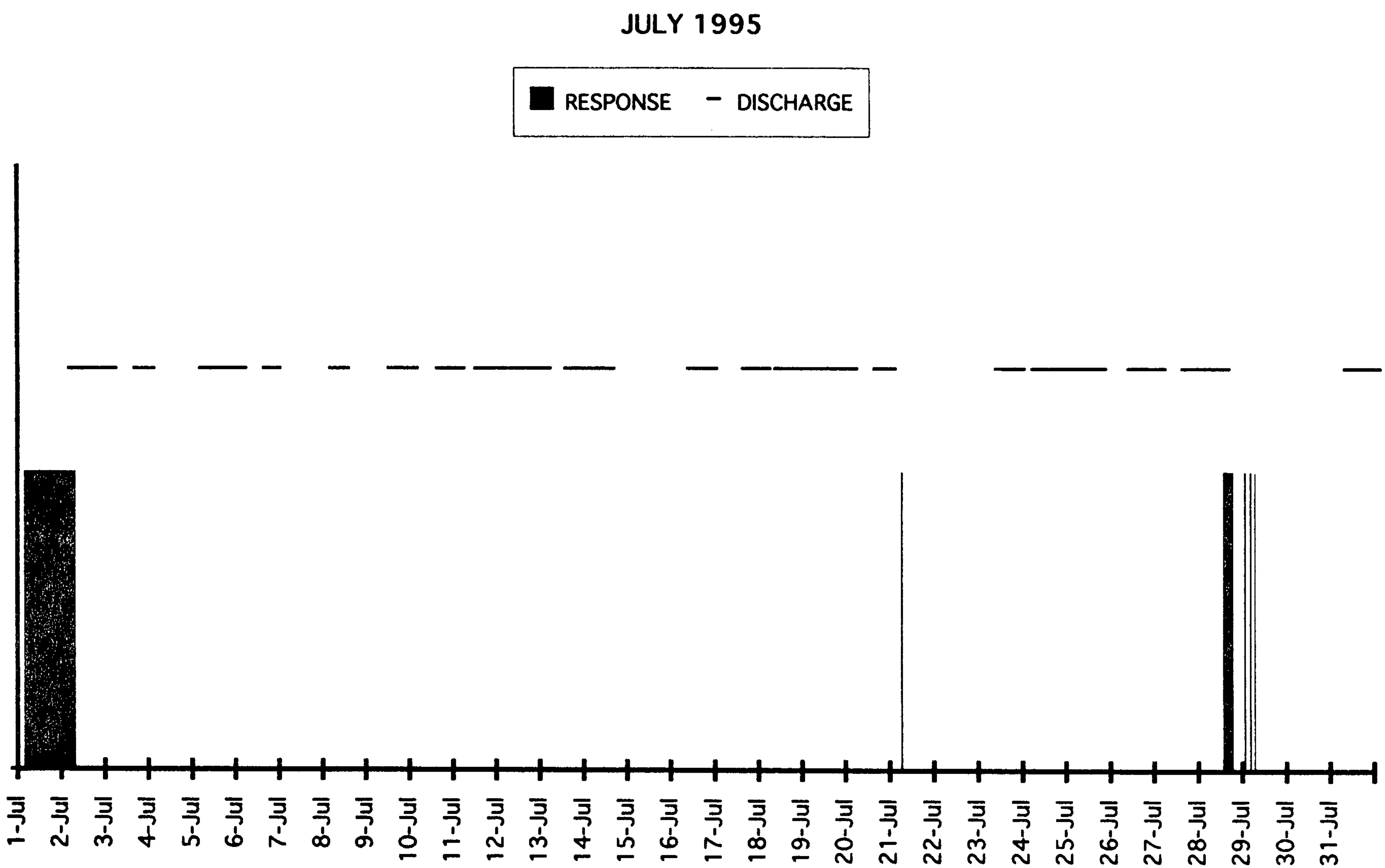

Figure 4-1b. "Out of control" responses and discharge periods of GWTF effluent to the Gunpowder River during July 1995.

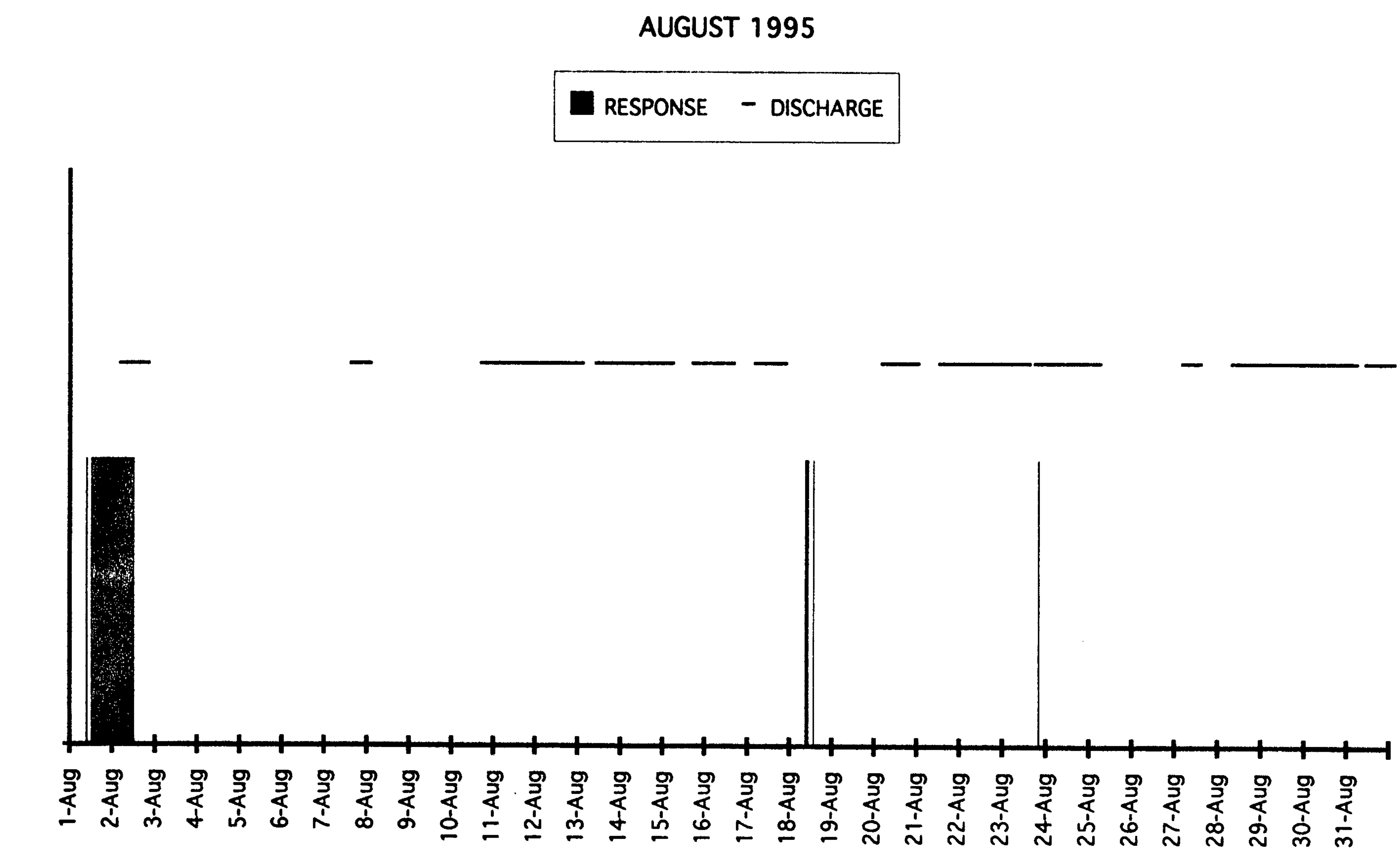

Figure 4-1c. "Out of control" responses and discharge periods of GWTF effluent to the Gunpowder River during August 1995.

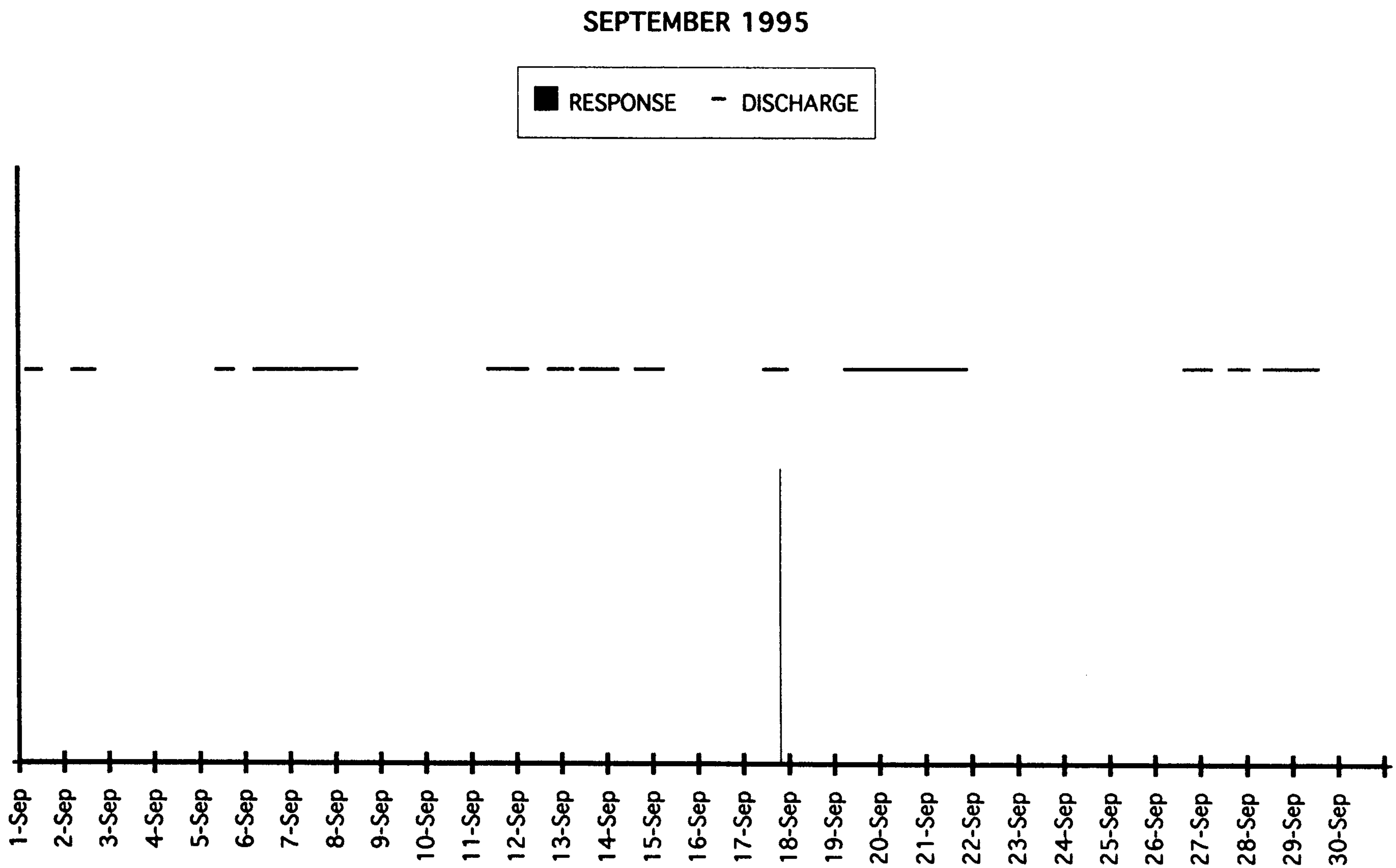

Figure 4-1d. "Out of control" responses and discharge periods of GWTF effluent to the Gunpower River during September 1995.

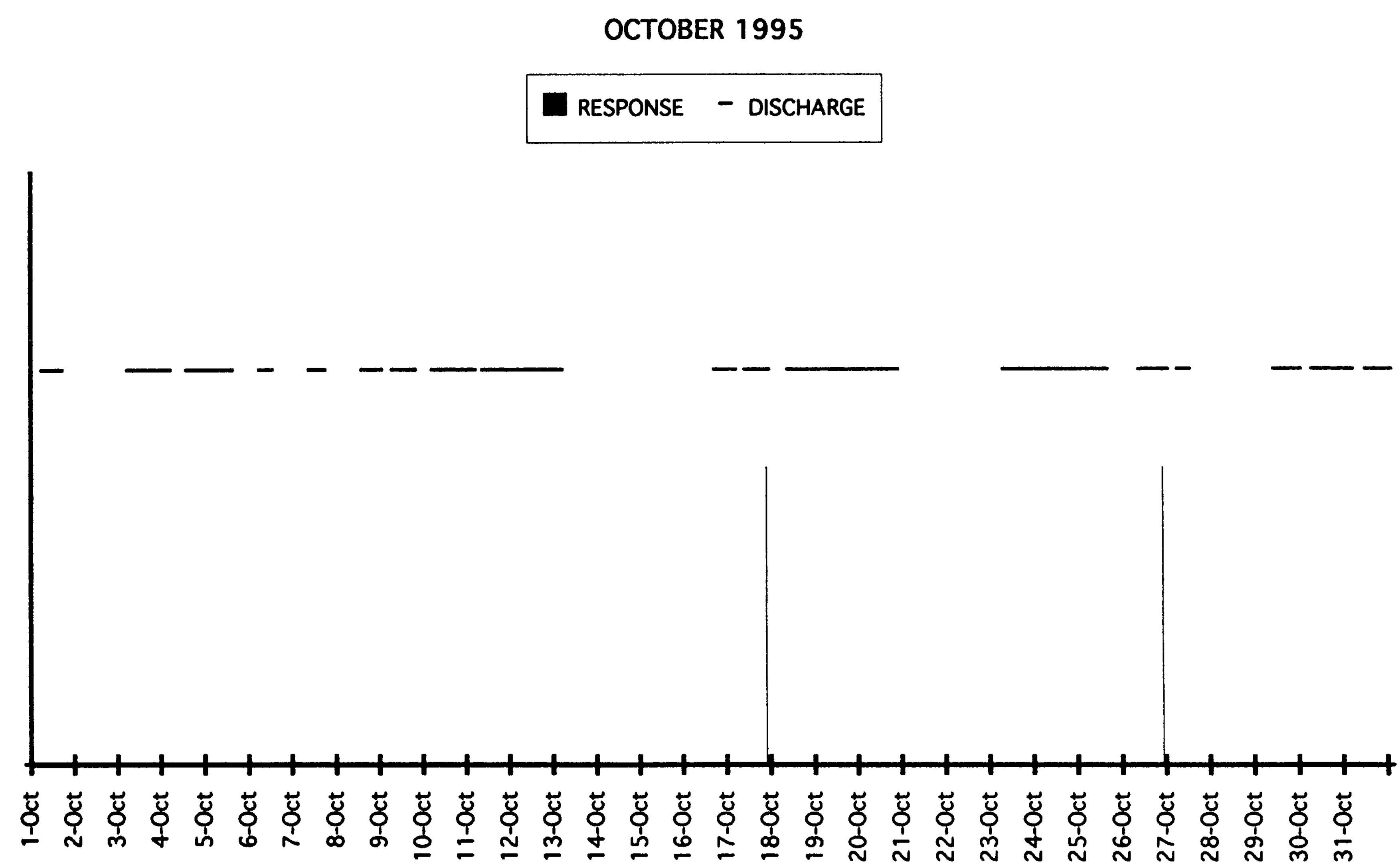

Figure 4-1e. "Out of control" responses and discharge periods of GWTF effluent to the Gunpower River during October 1995.

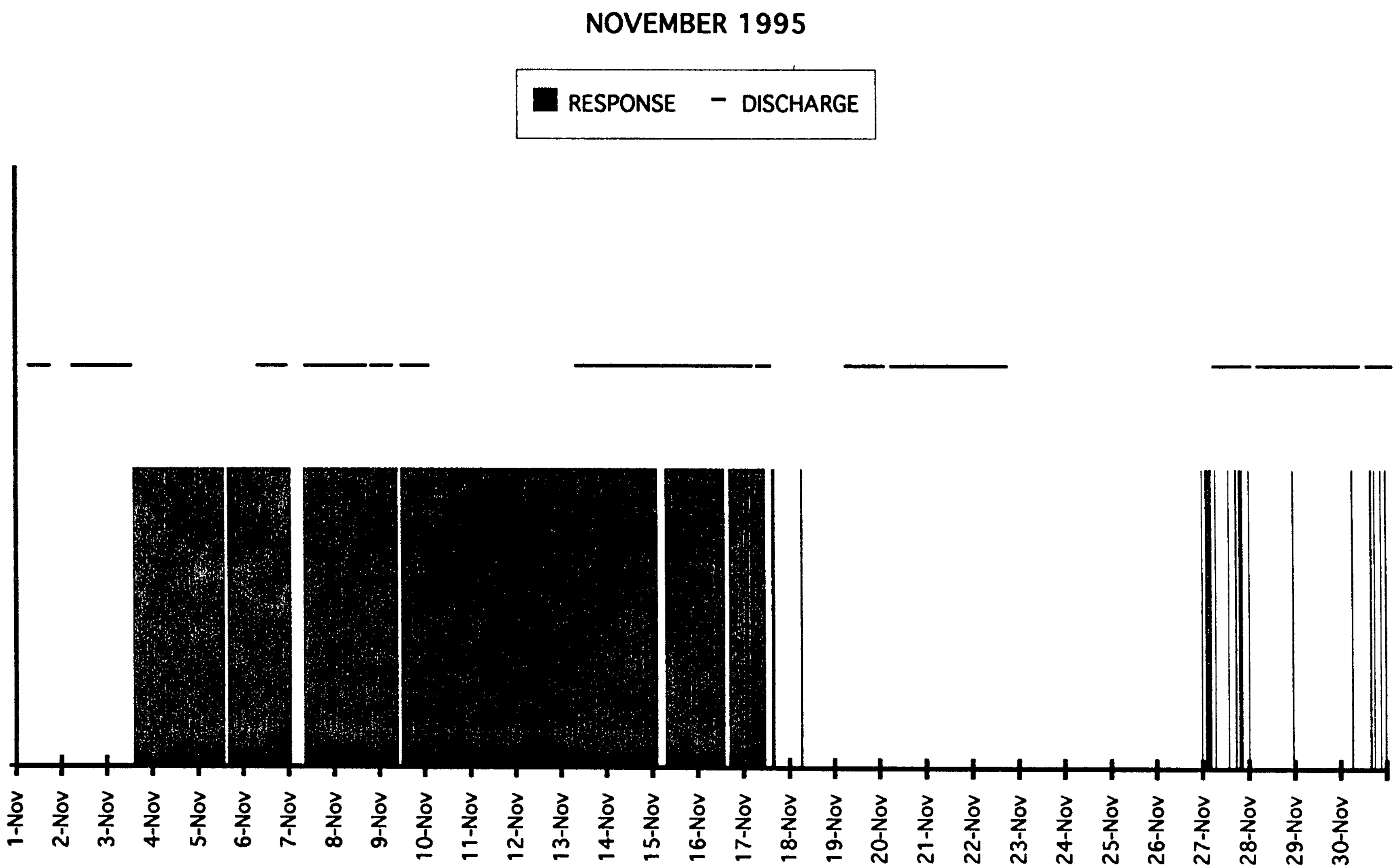

Figure 4-1f. "Out of control" responses and discharge periods of GWTF effluent to the Gunpowder River during November 1995.

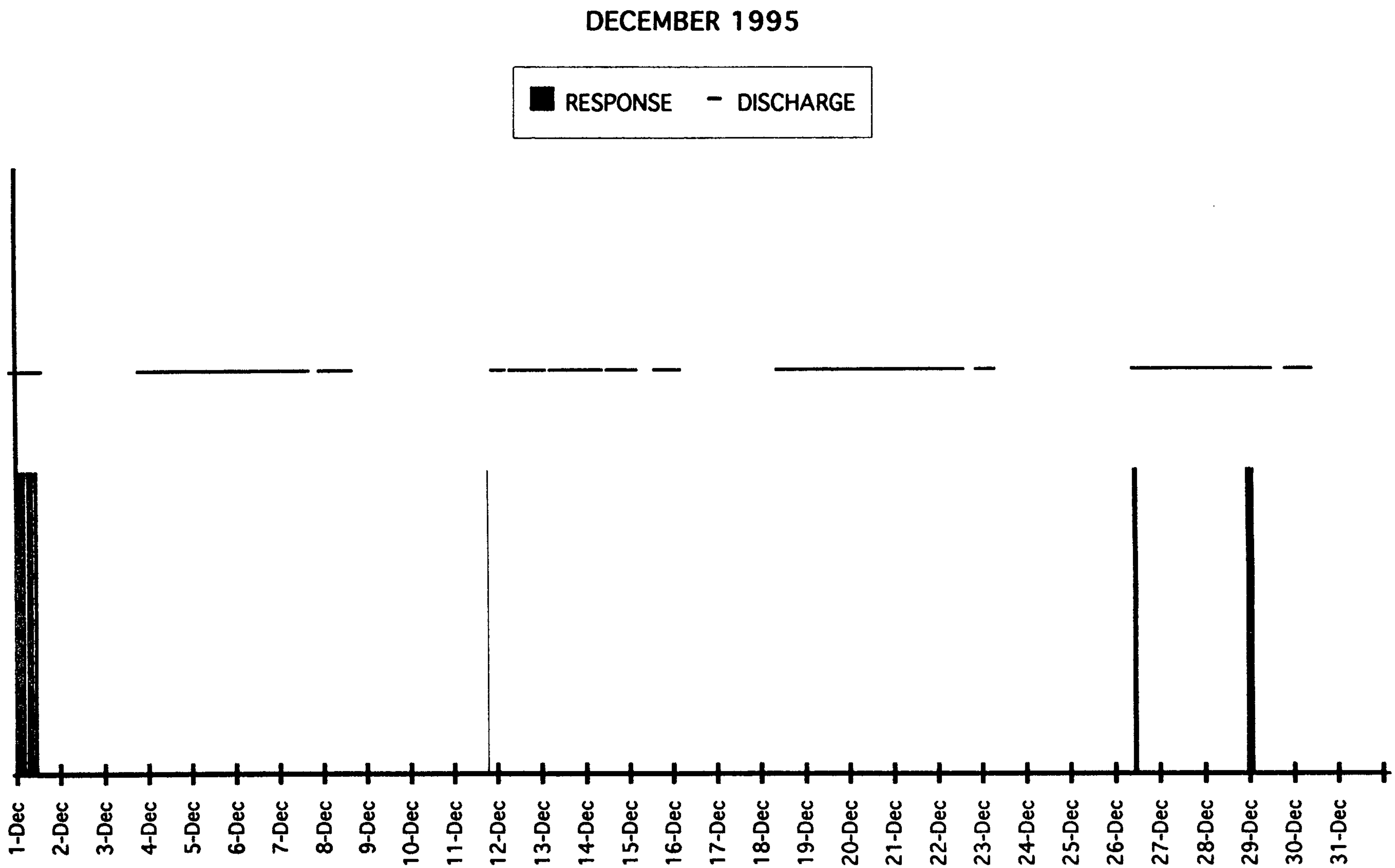

Figure 4-1g. "Out of control" responses and discharge periods of GWTF to the Gunpowder River during December 1995.

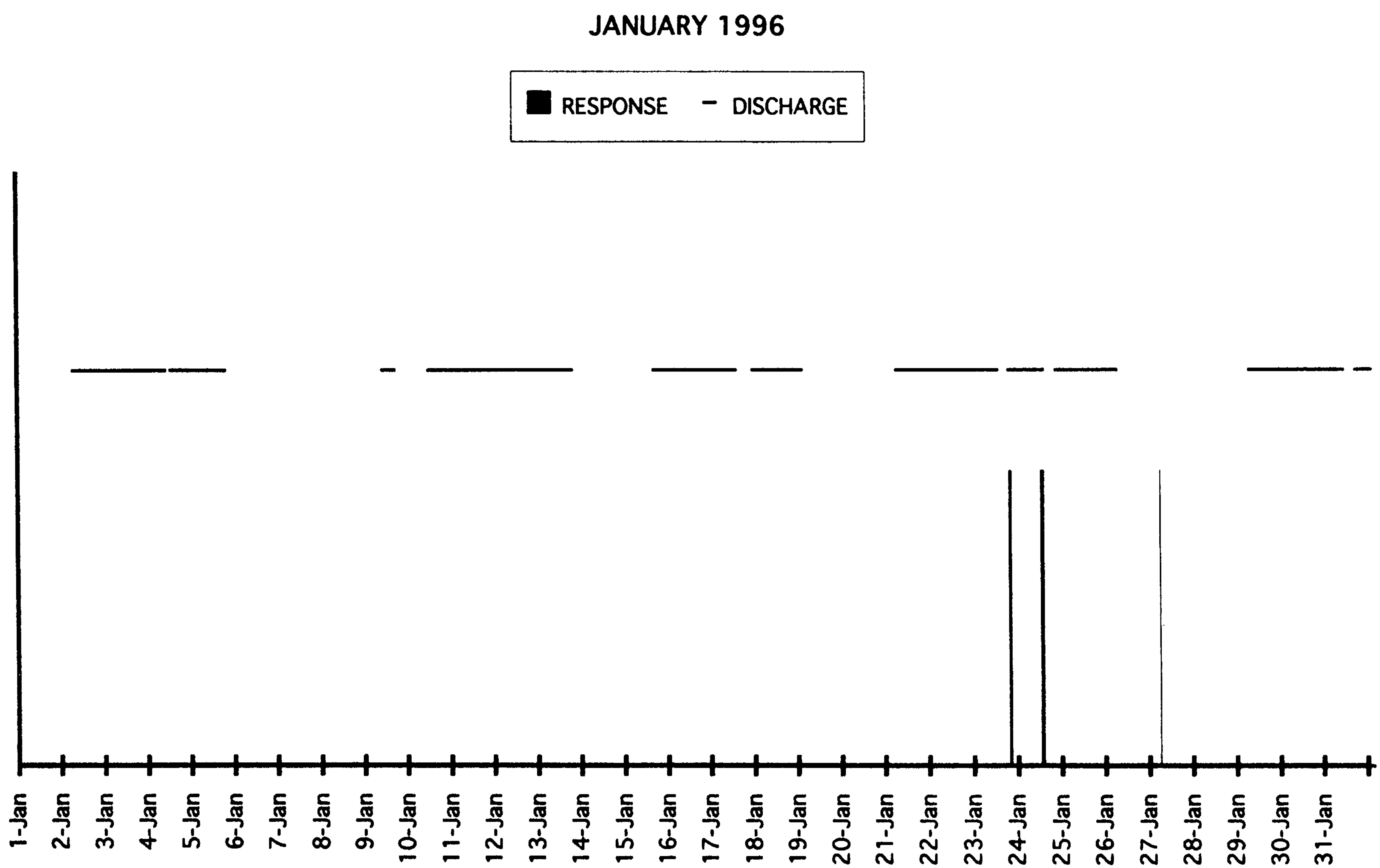

Figure 4-1h. "Out of control" responses and discharge periods of GWTF to the Gunpowder River during January 1996.

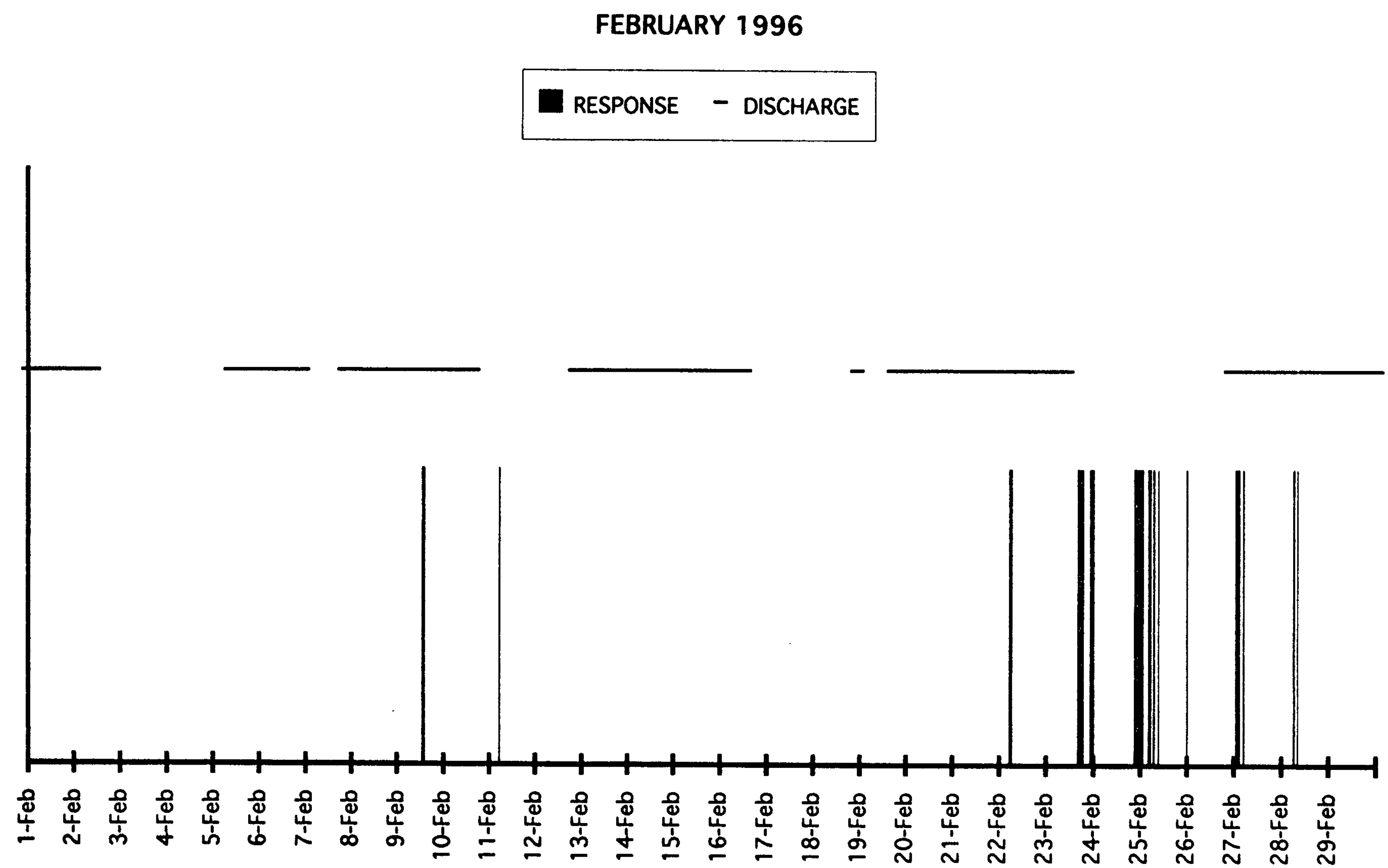

Figure 4-1i. "Out of control" responses and discharge periods of GWTF effluent to the Gunpowder River during February 1996.

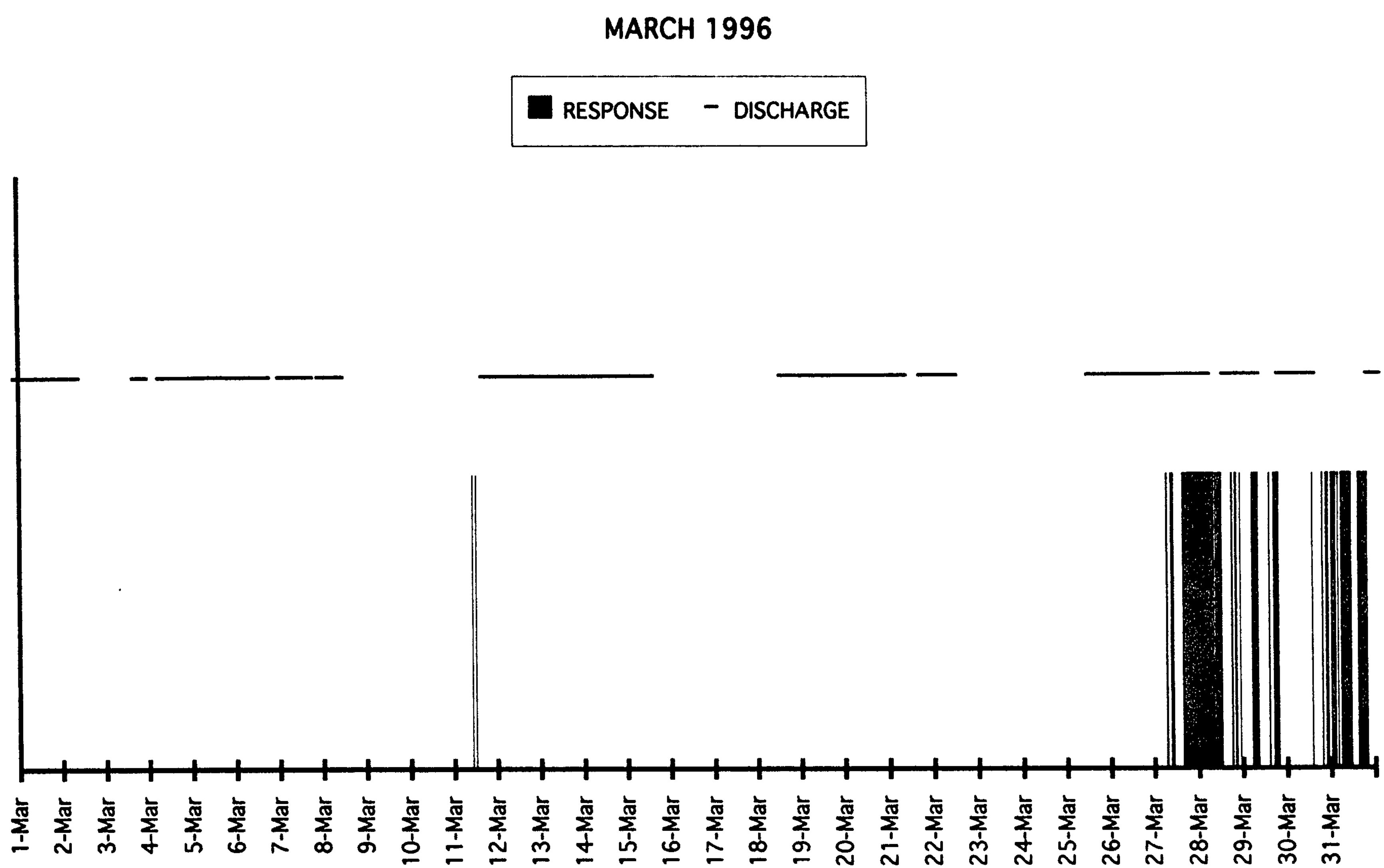

Figure 4-1j. "Out of control" responses and discharge periods of GWTF effluent to the Gunpowder River during March 1996.

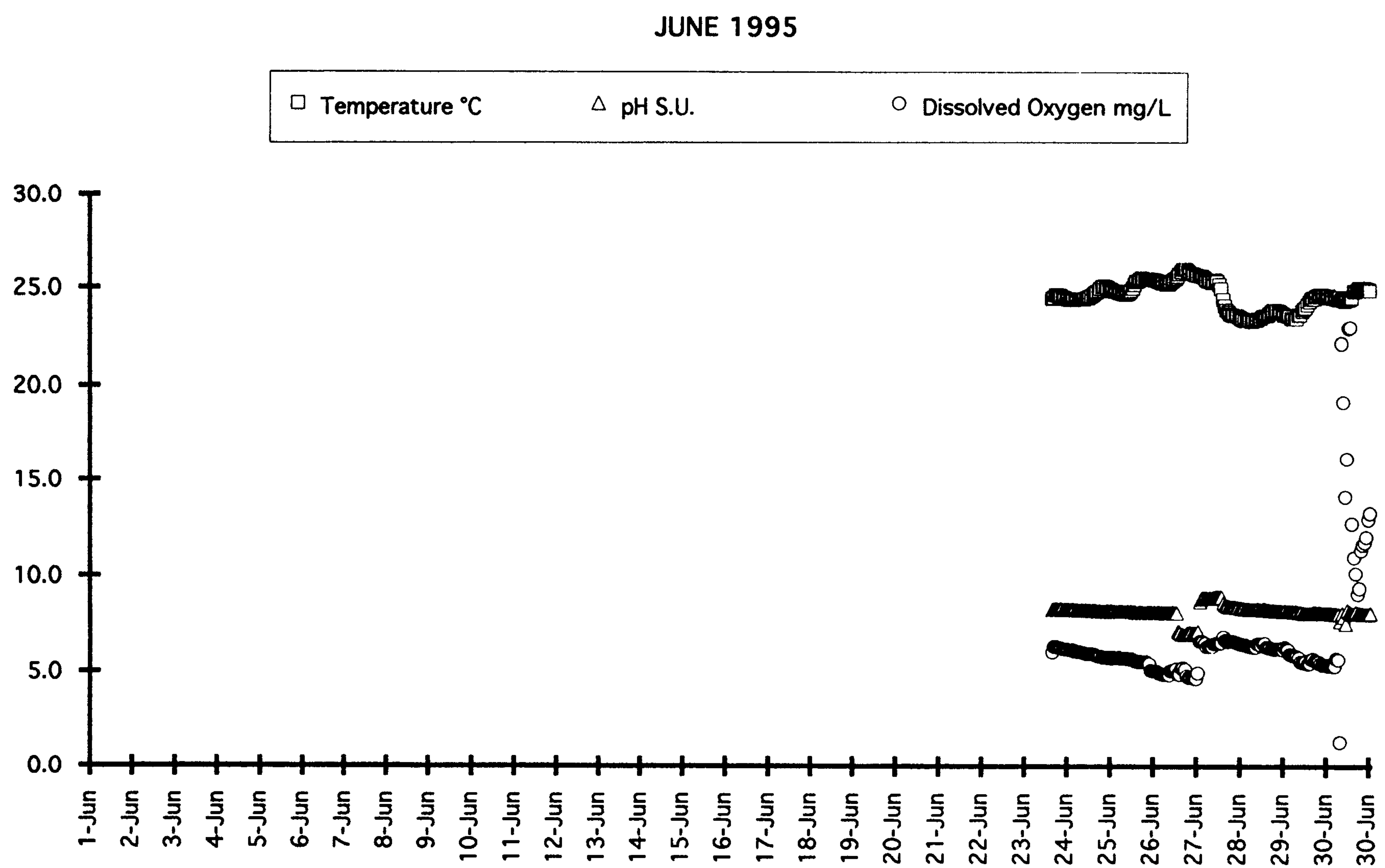

Figure 4-2.1a. GWTF effluent temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during June 1995.

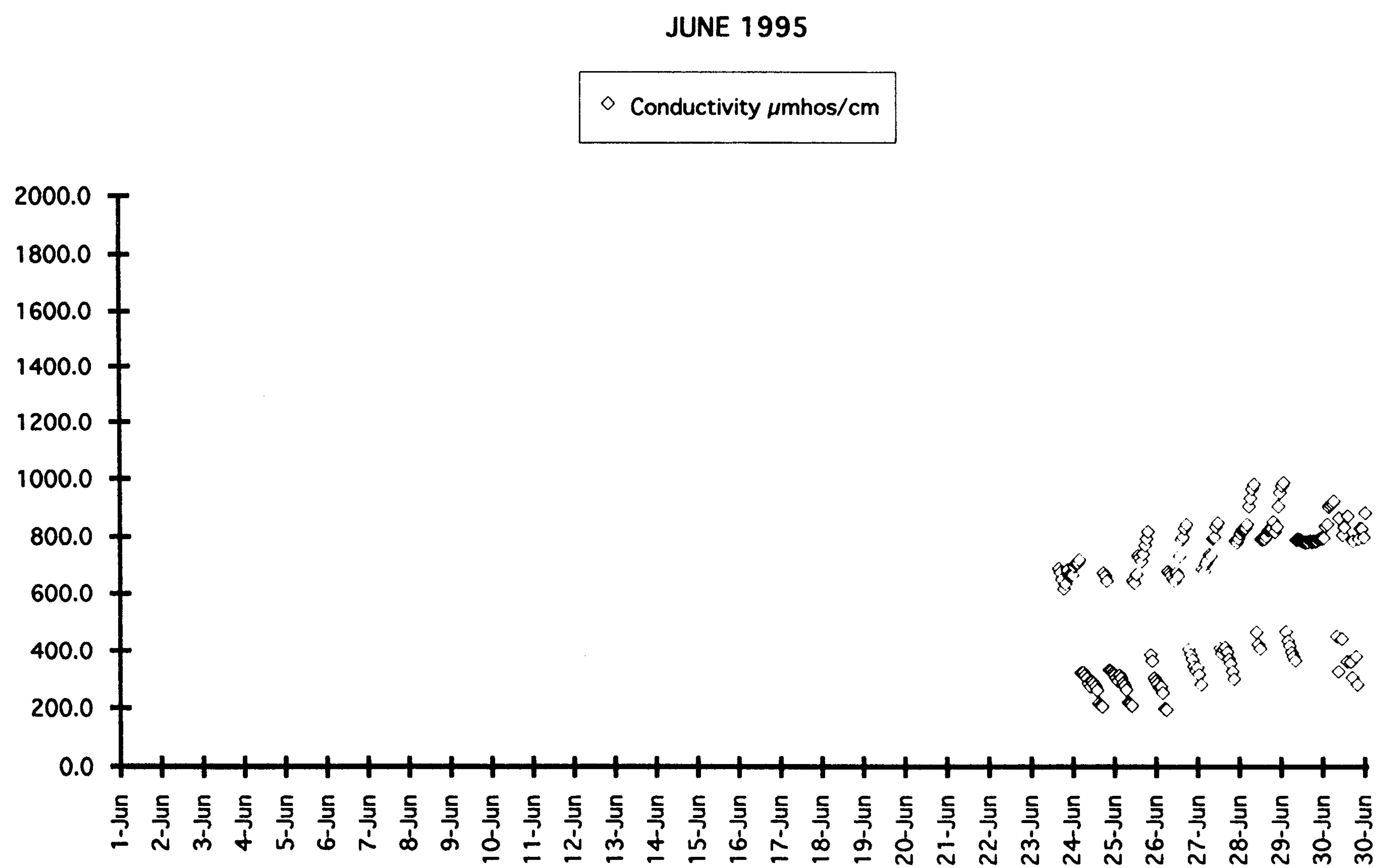

Figure 4-2.1b. GWTF effluent conductivity data obtained by the Hydrolab System during June 1995.

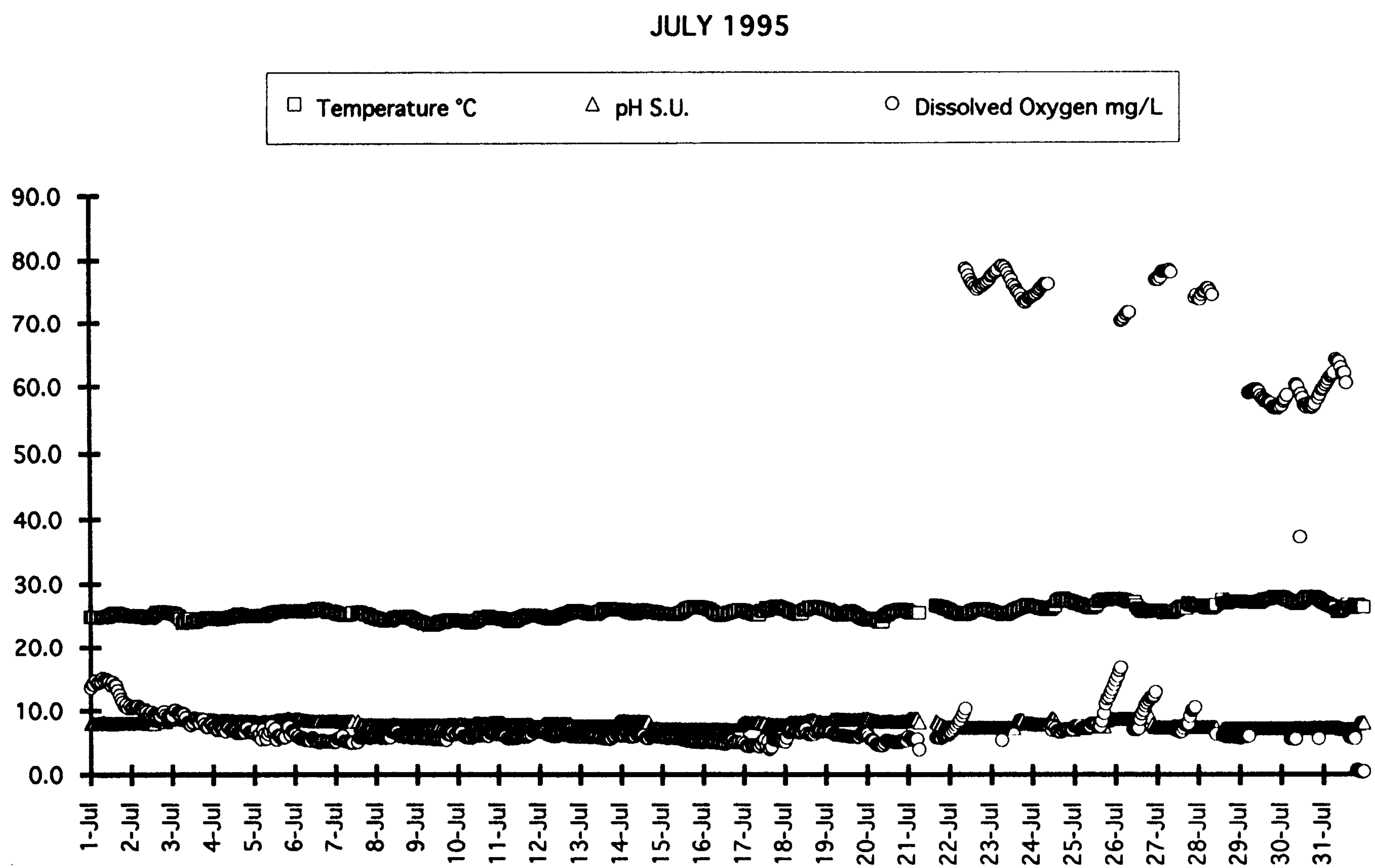

Figure 4-2.1c. GWTF effluent temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during July 1995.

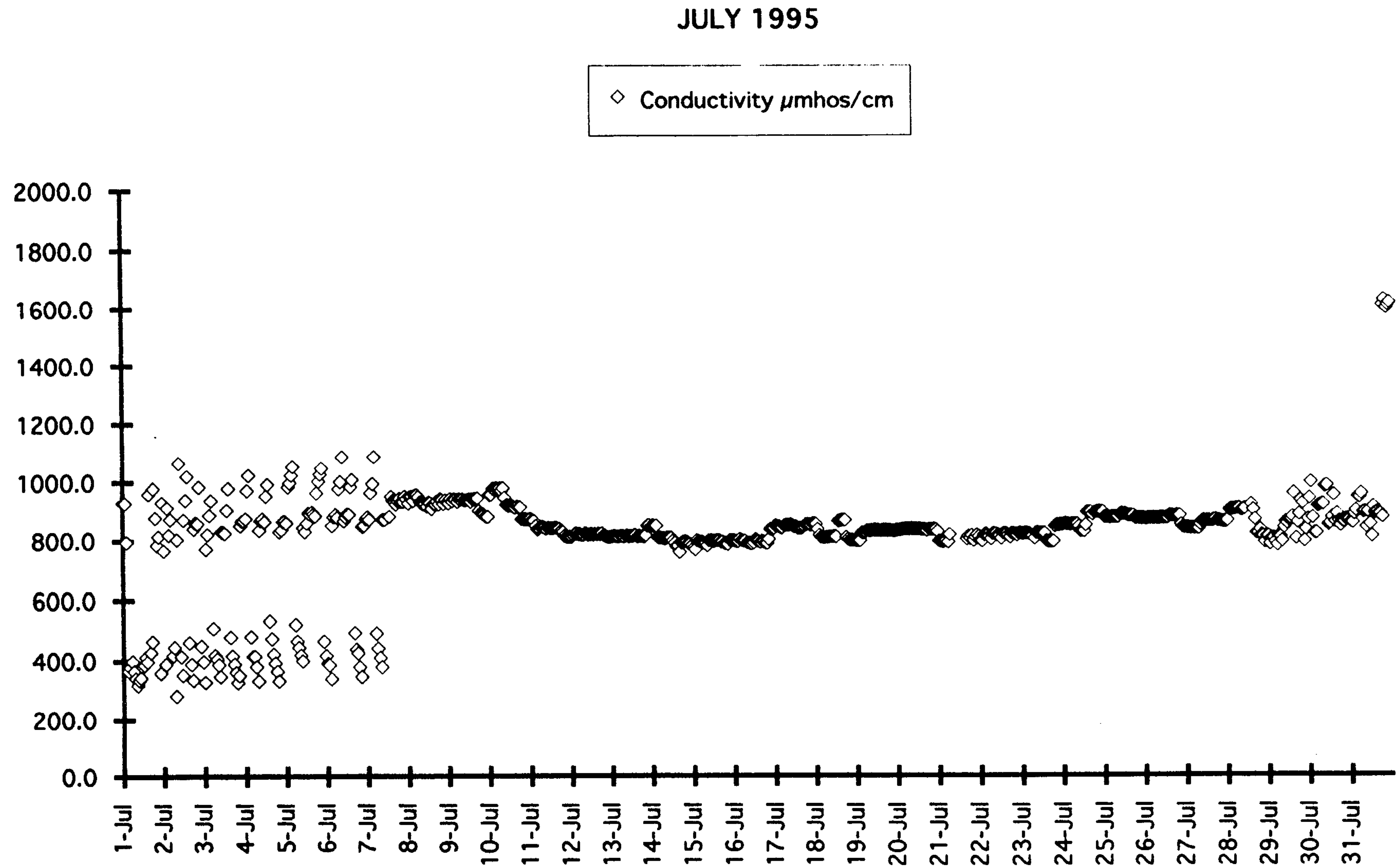

Figure 4-2.1d. GWTF effluent conductivity data obtained by the Hydrolab System during July 1995.

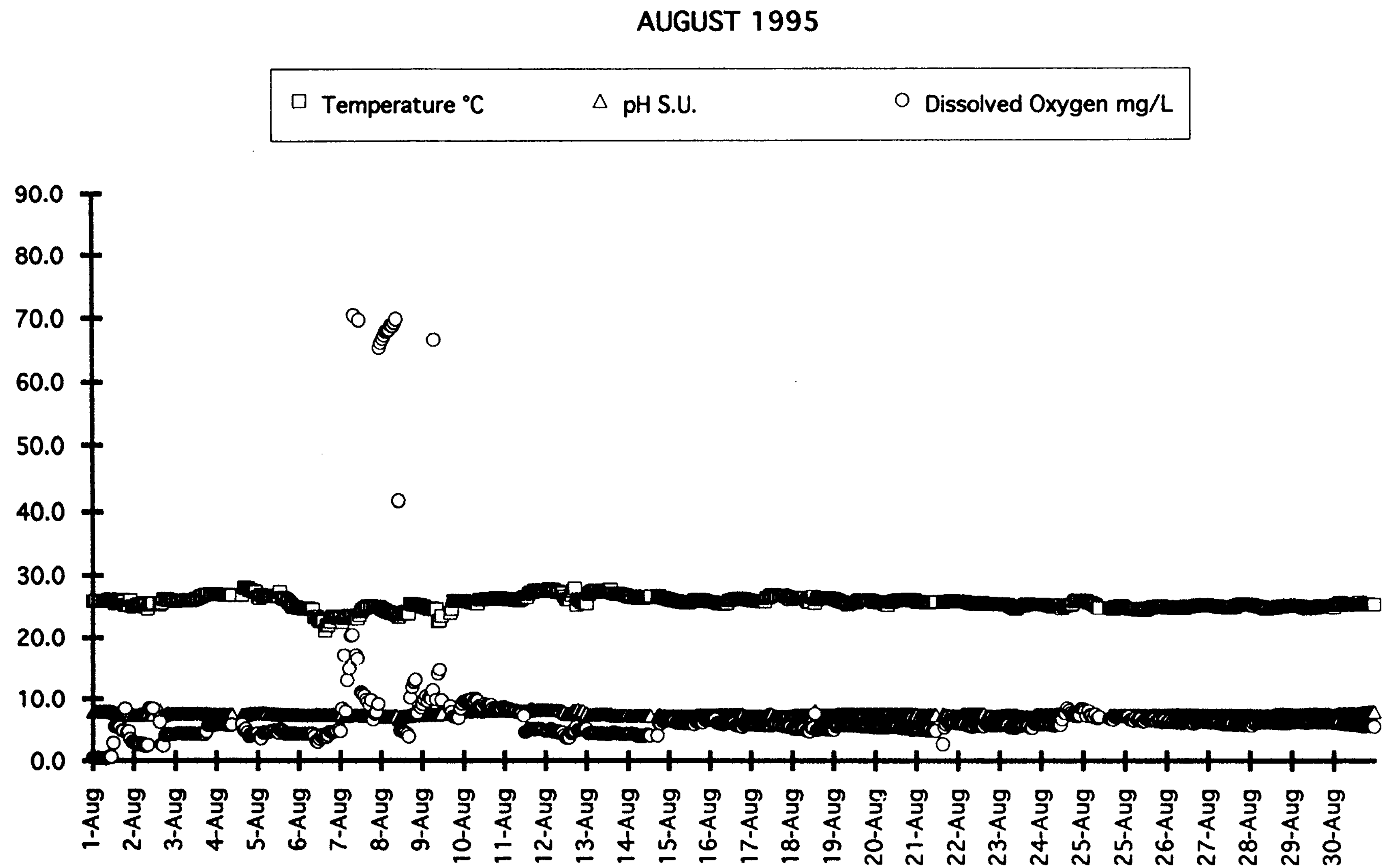

Figure 4-2.1e. GWTF effluent temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during August 1995.

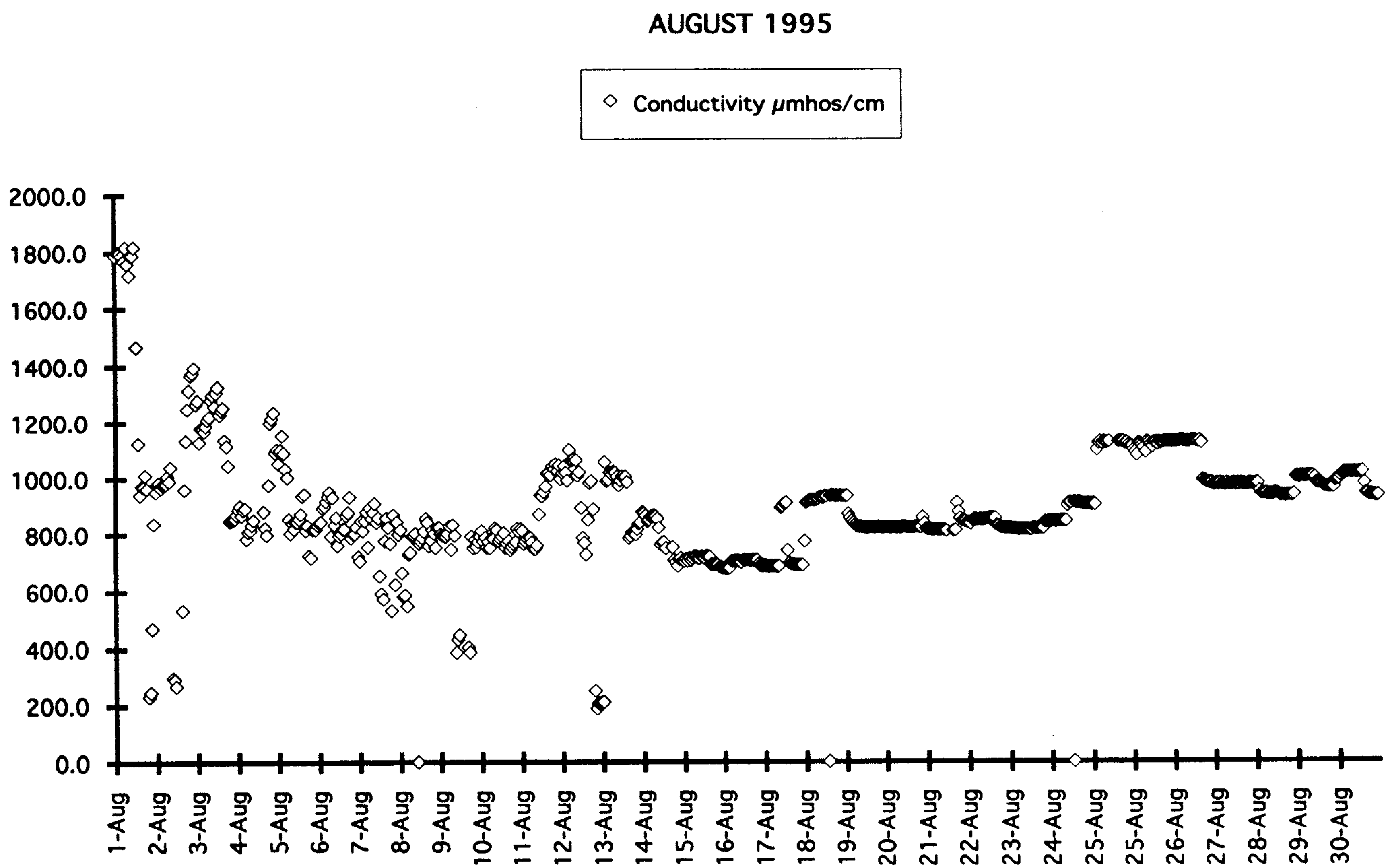

Figure 4-2.1f. GWTF effluent conductivity data obtained by the Hydrolab System during August 1995.

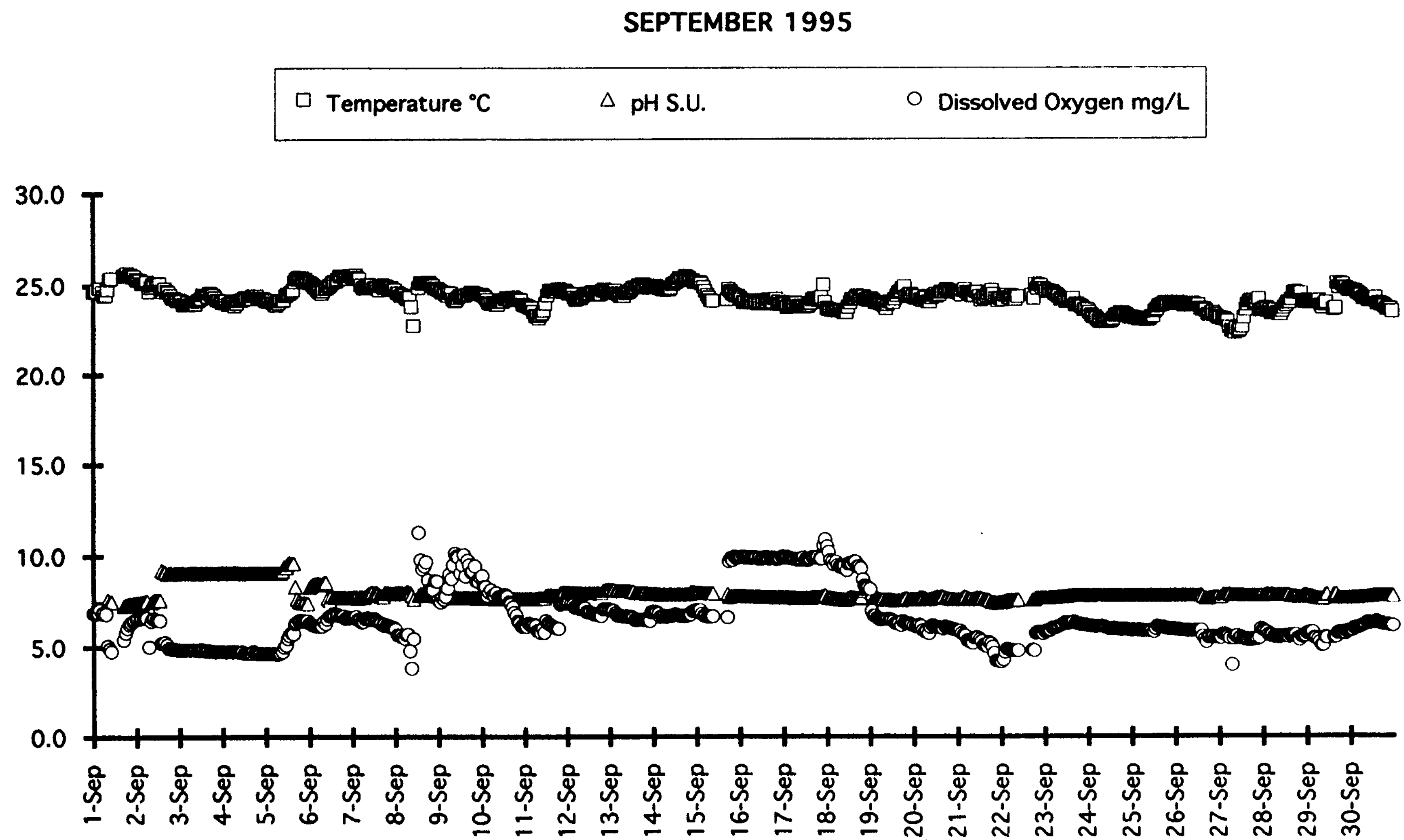

Figure 4-2.1g. GWTF effluent temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during September 1995.

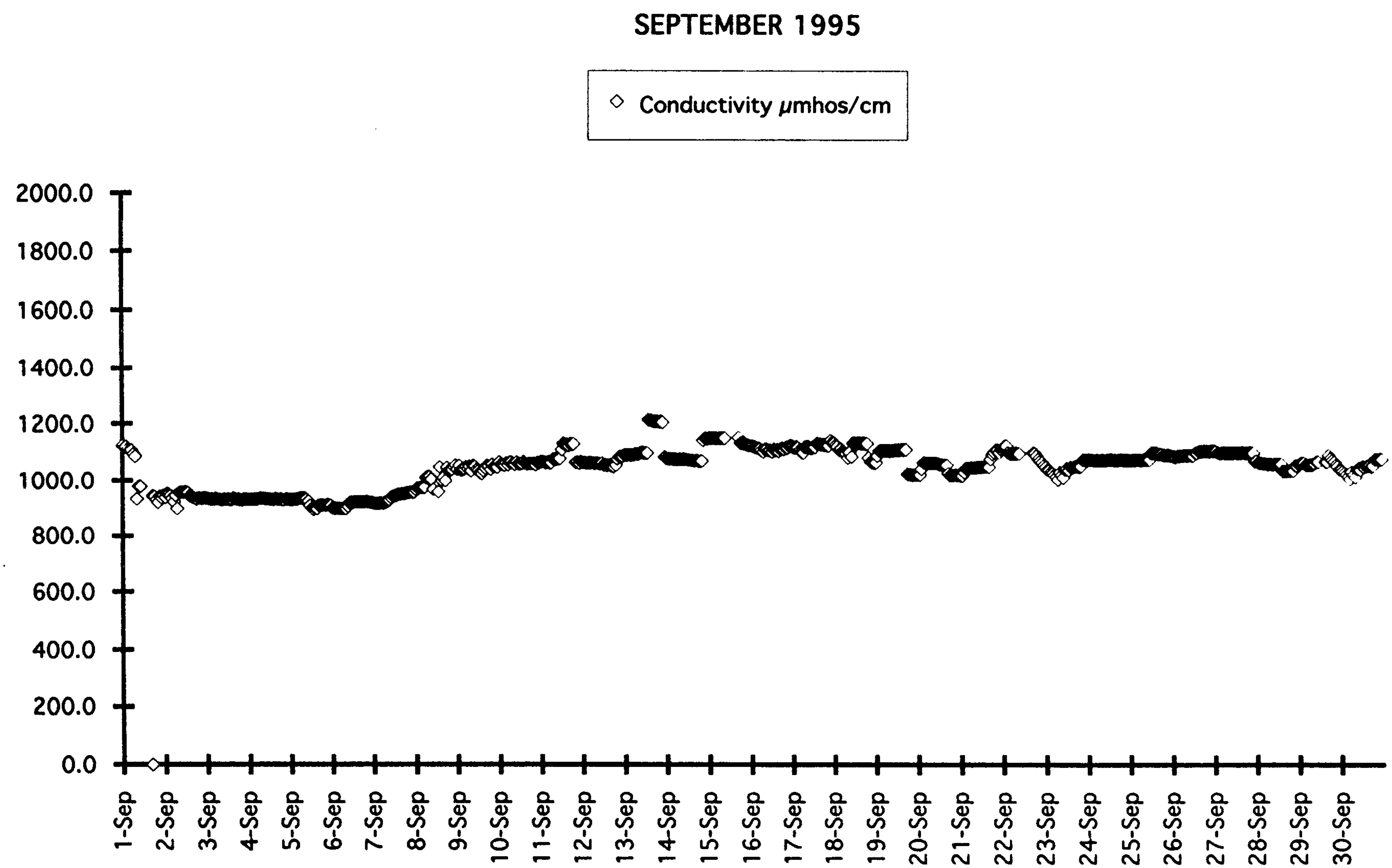

Figure 4-2.1h. GWTF effluent conductivity data obtained by the Hydrolab System during September 1995.

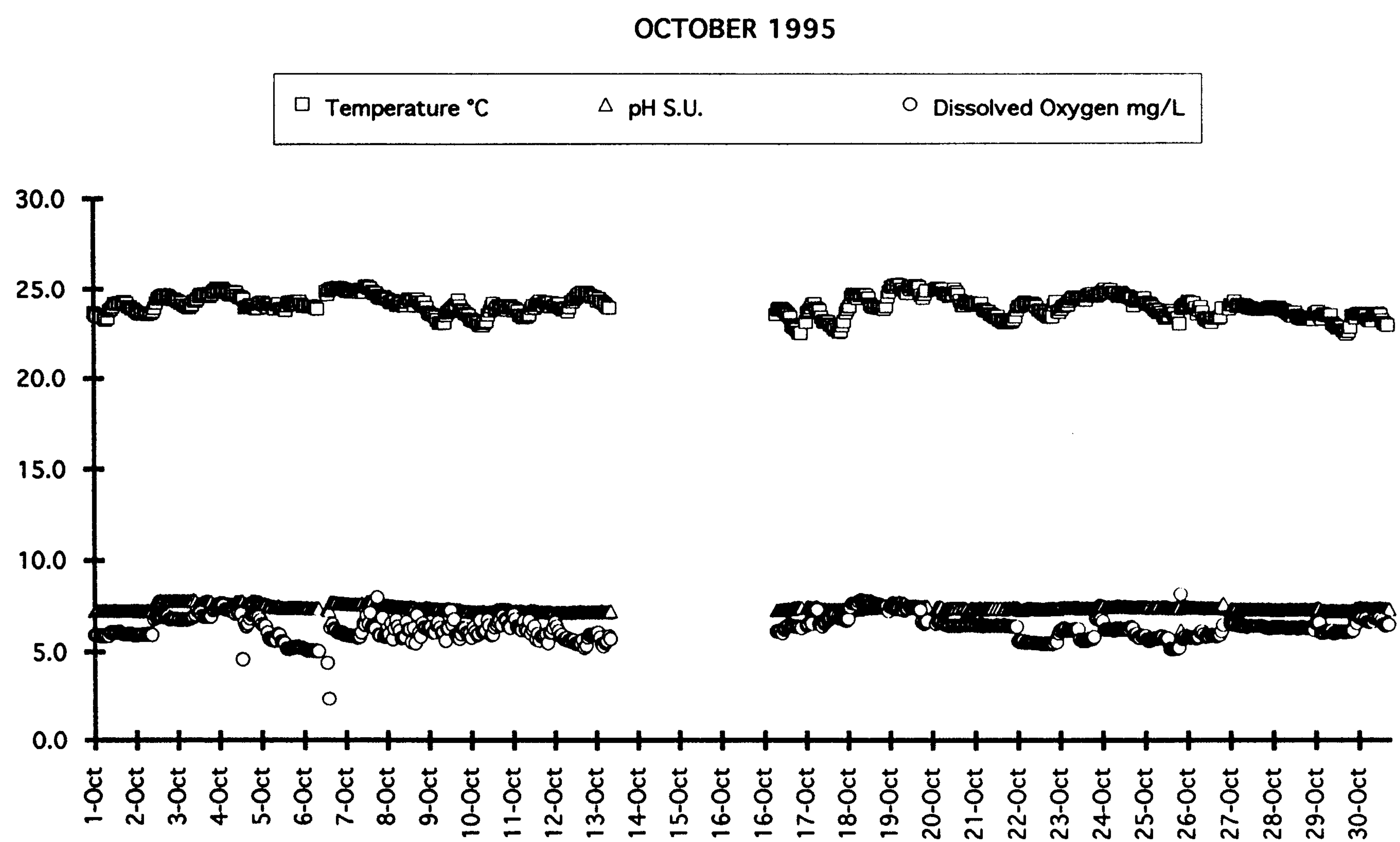

Figure 4-2.1i. GWTF effluent temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during October 1995.

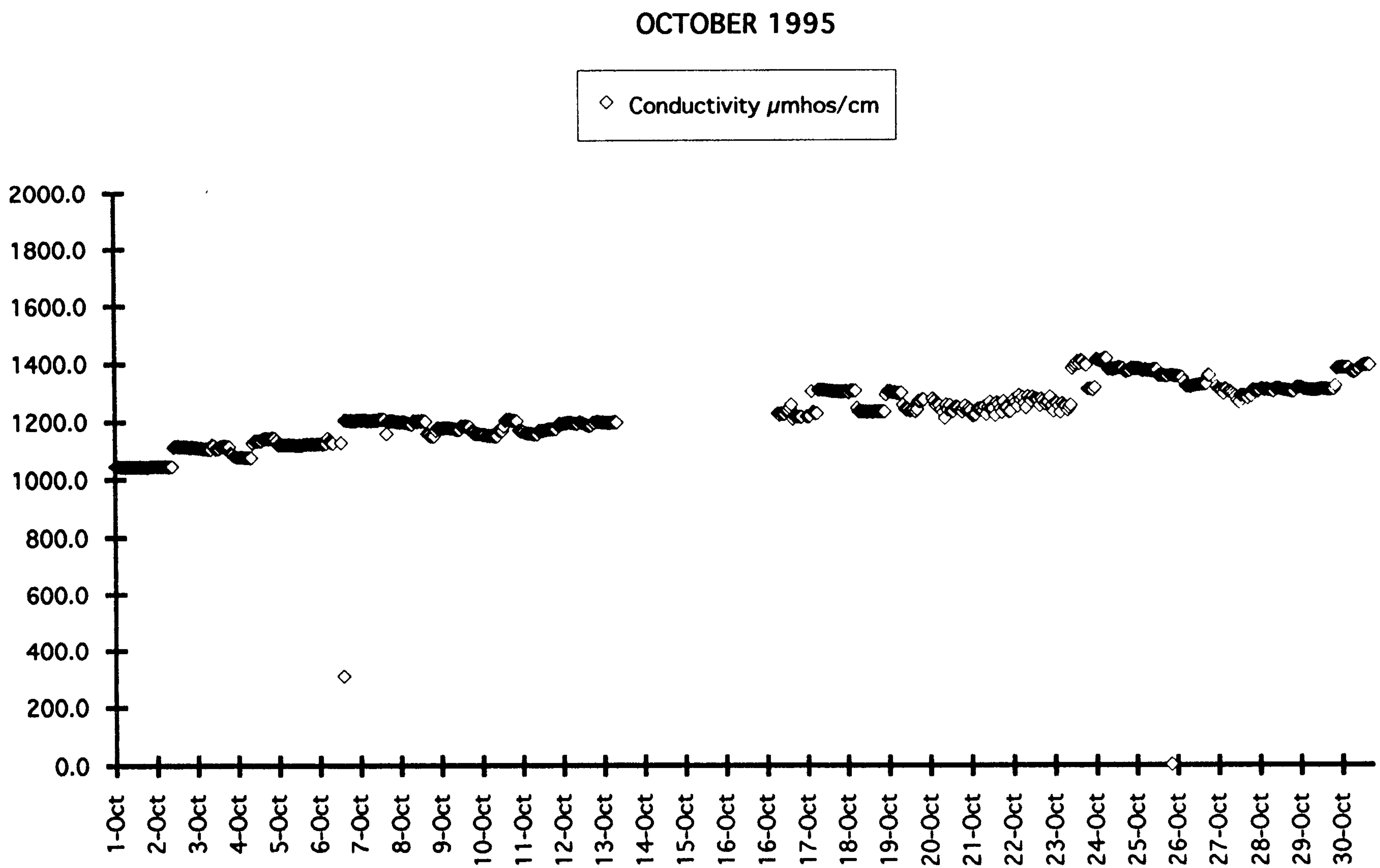

Figure 4-2.1j. GWTF effluent conductivity data obtained by the Hydrolab System during October 1995.

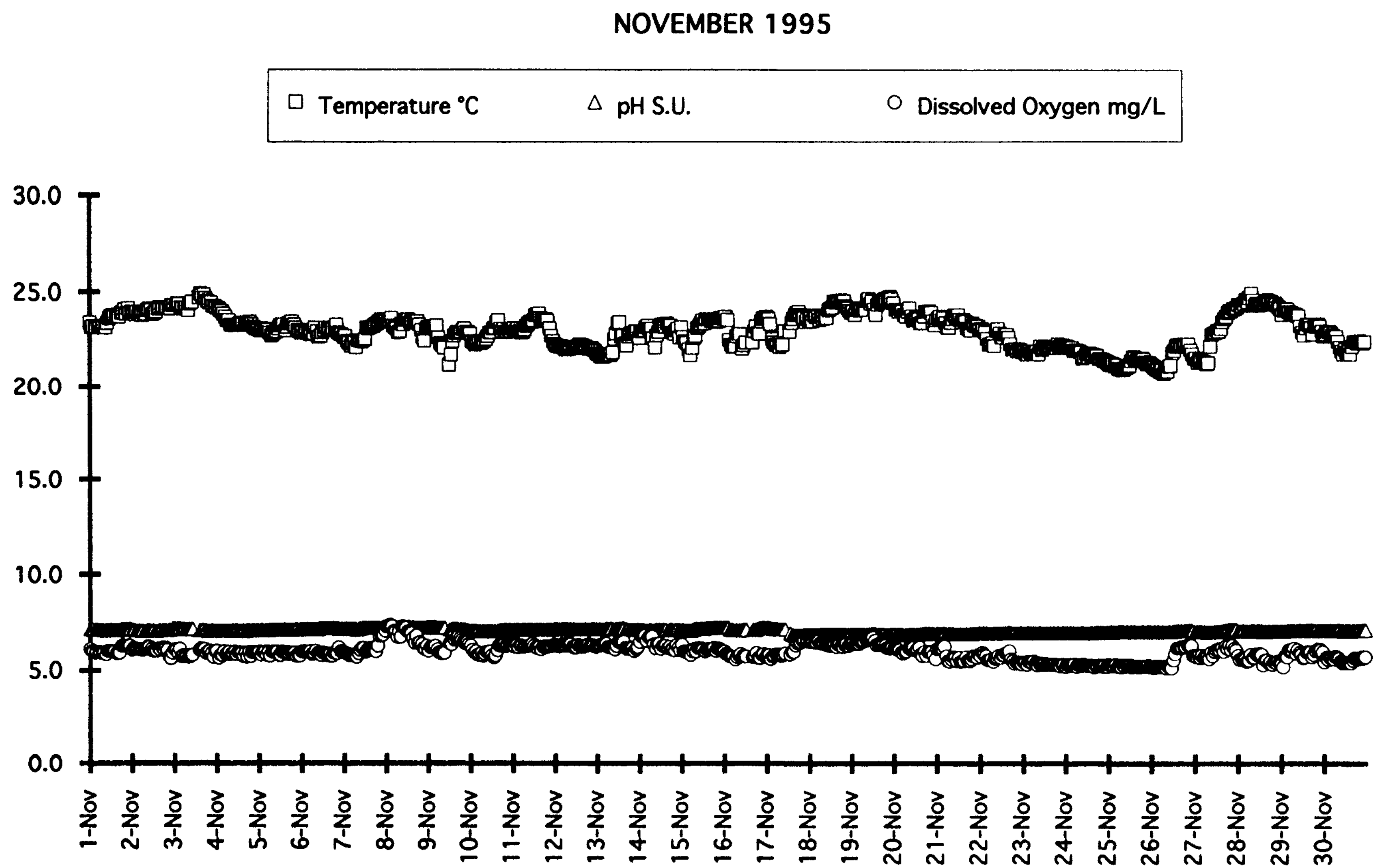

Figure 4-2.1k. GWTF effluent temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during November 1995.

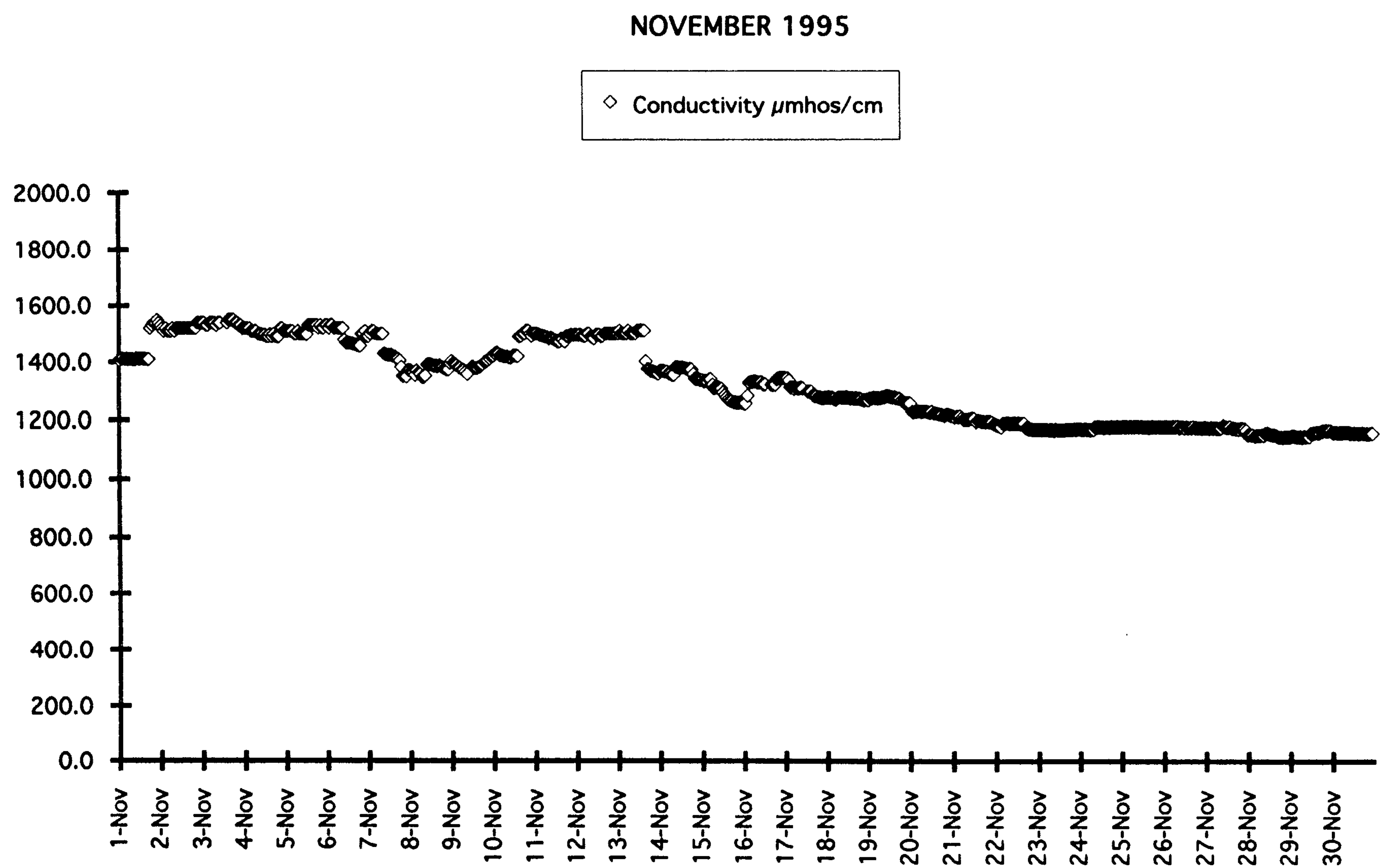

Figure 4-2.1l. GWTF effluent conductivity data obtained by the Hydrolab System during November 1995.

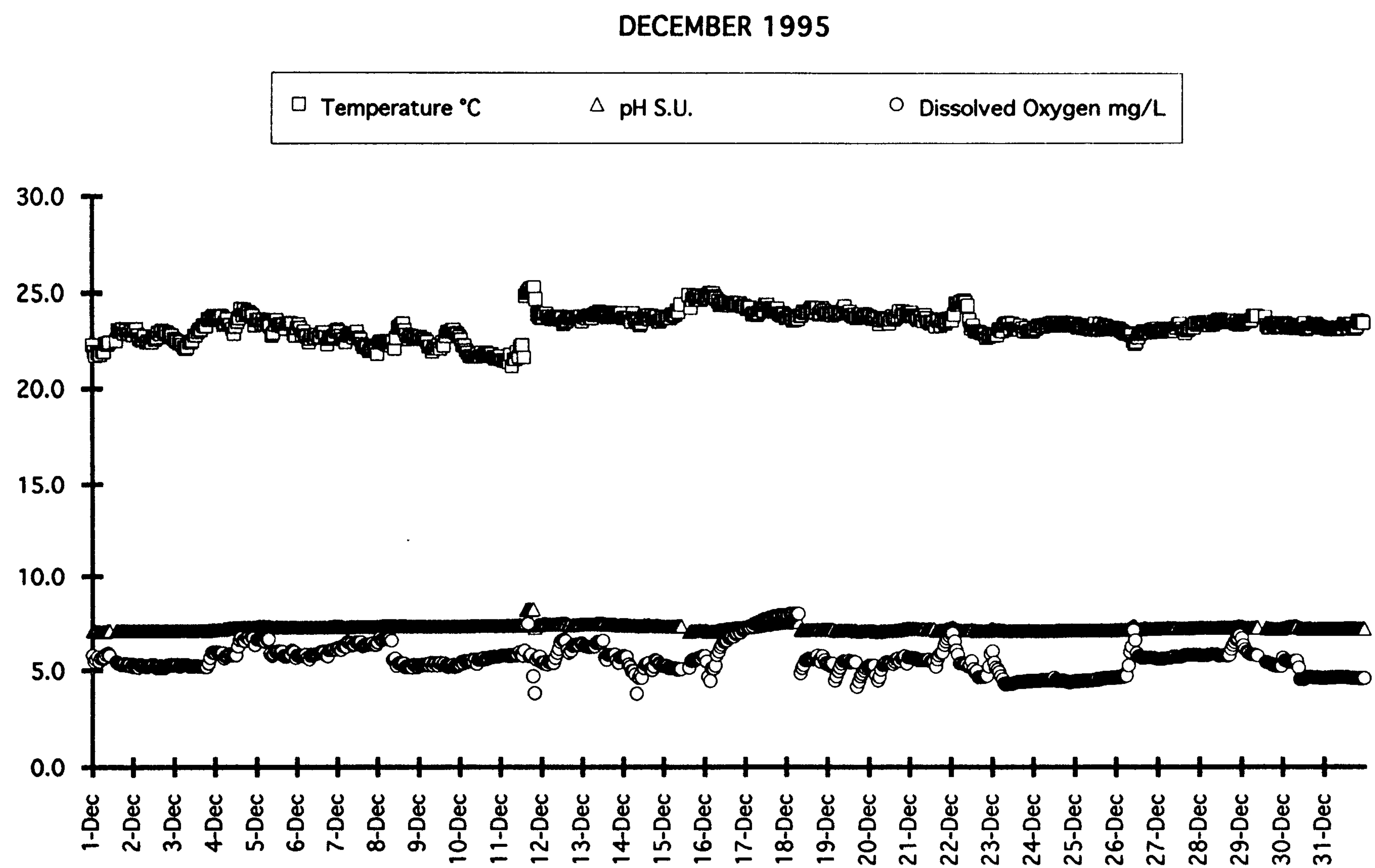

Figure 4-2.1m. GWTF effluent temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during December 1995.

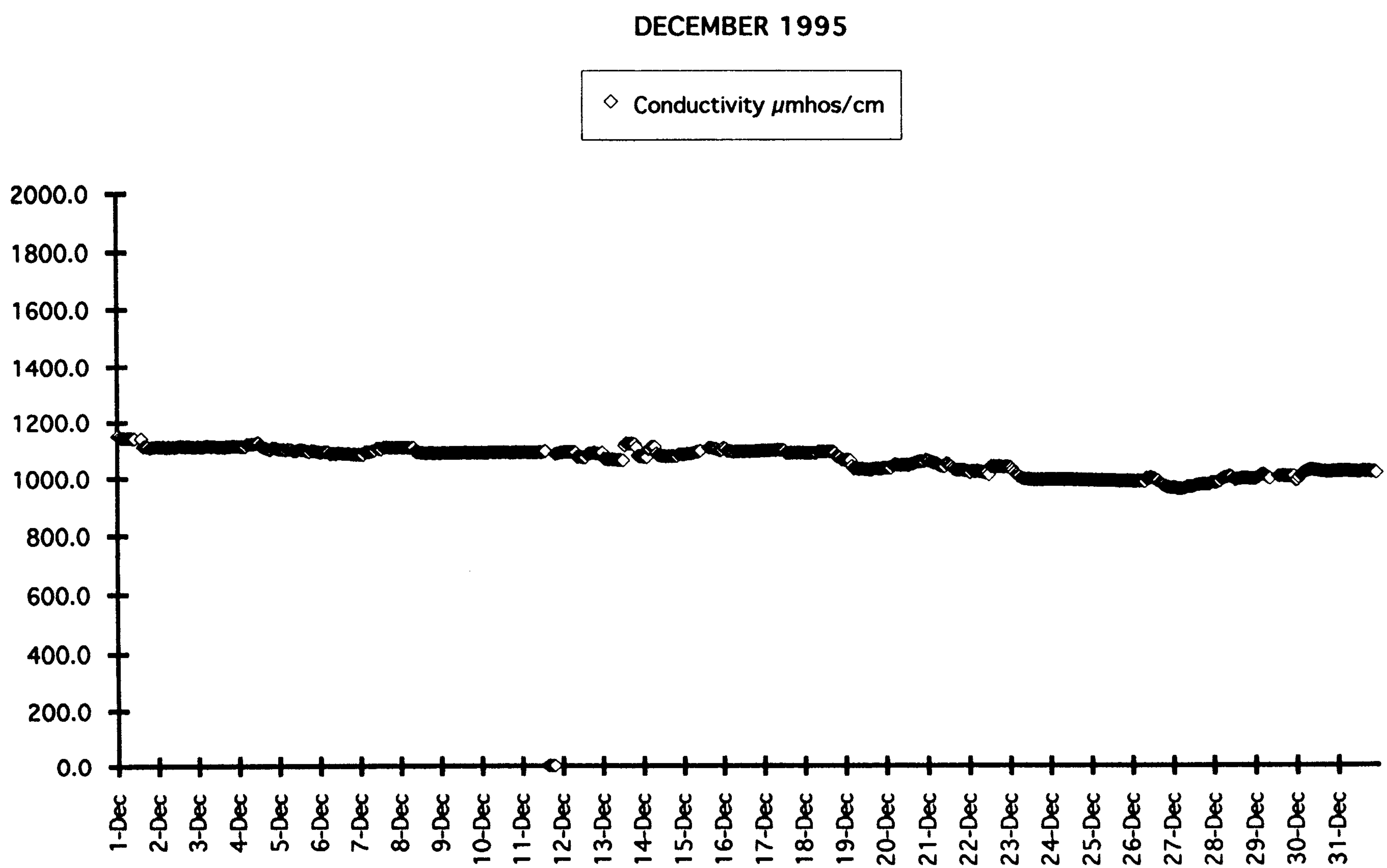

Figure 4-2.1n. GWTF effluent conductivity data obtained by the Hydrolab System during December 1995.

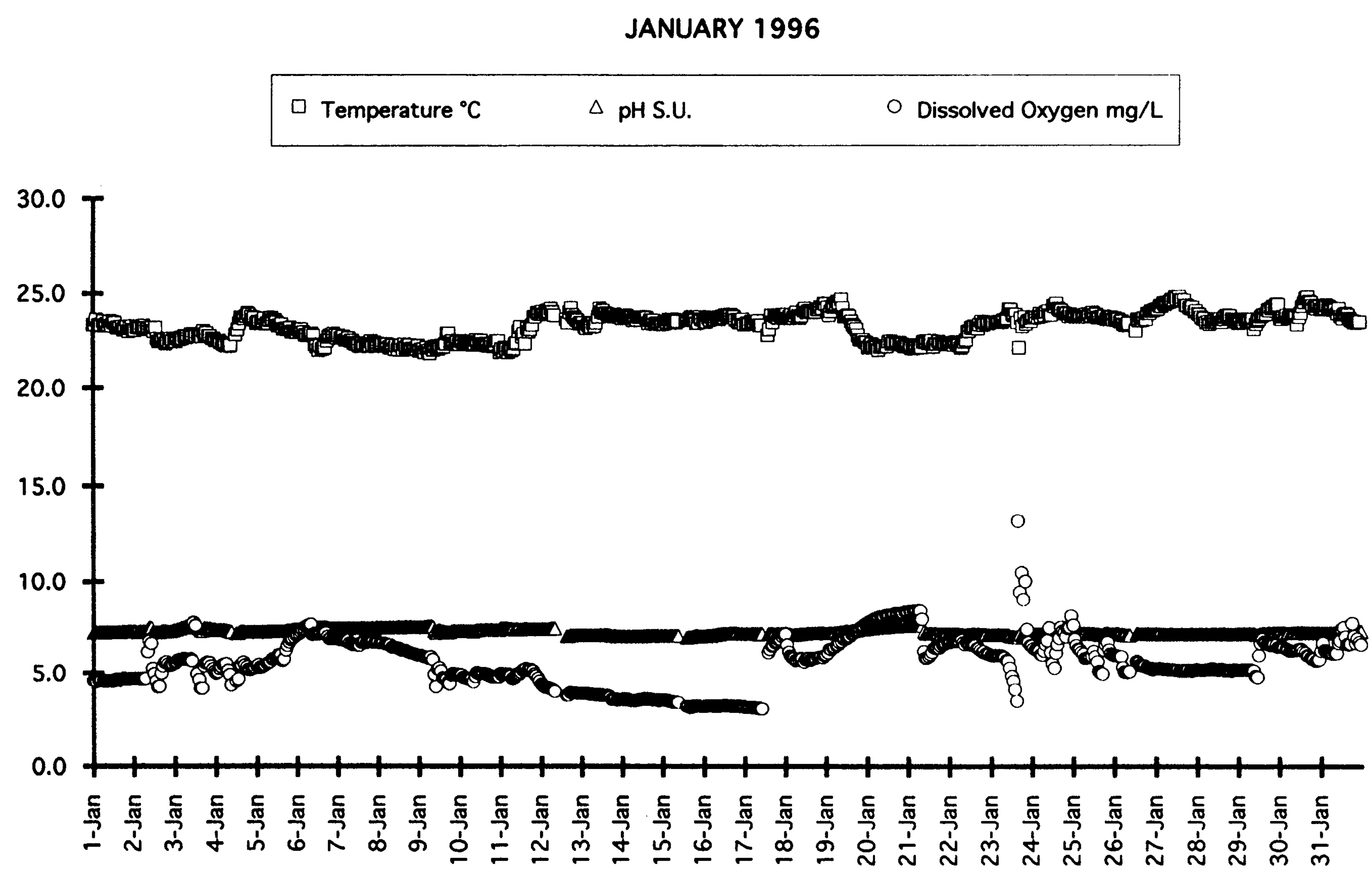

Figure 4-2.1o. GWTF effluent temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during January 1996.

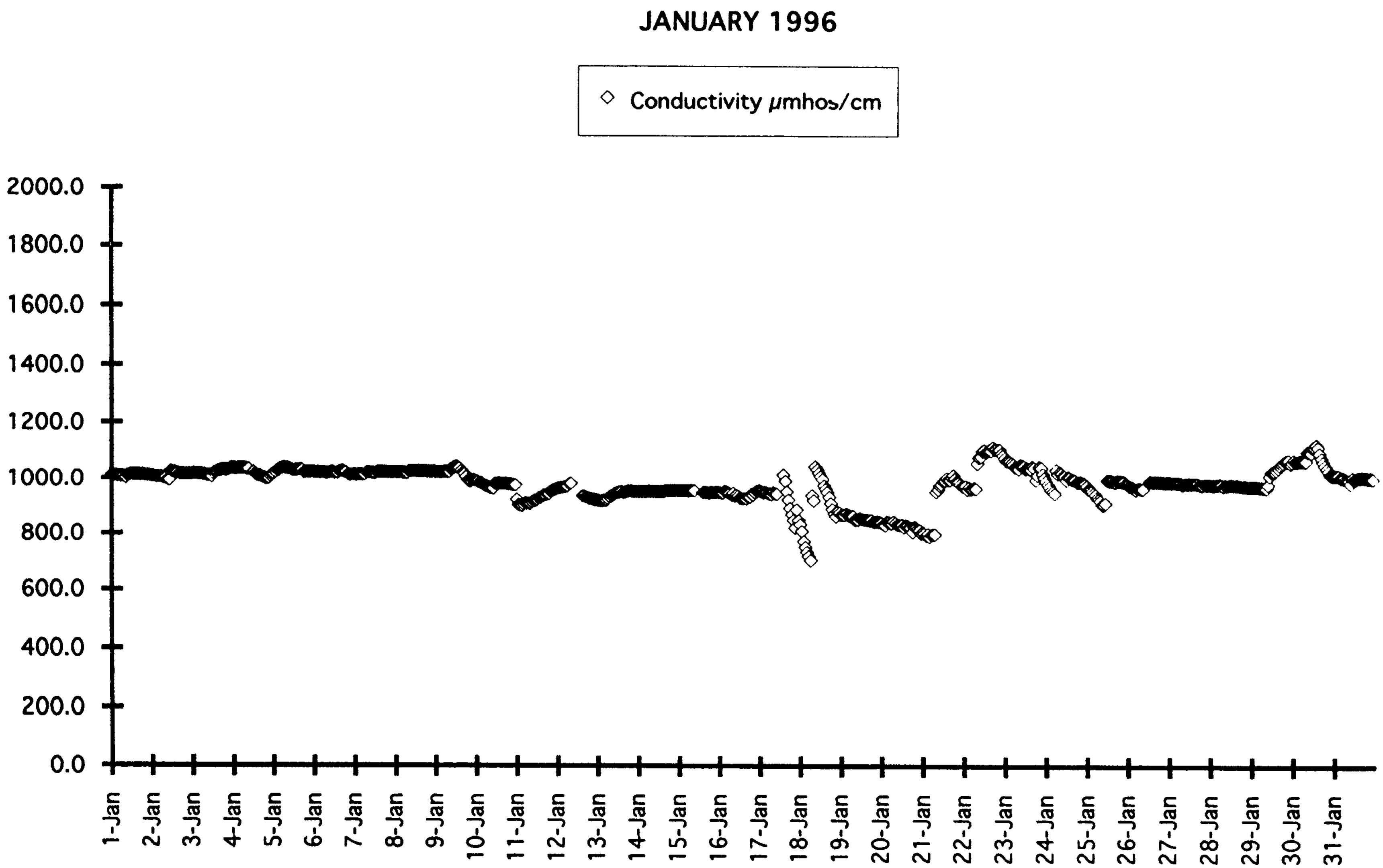

Figure 4-2.1p. GWTF effluent conductivity data obtained by the Hydrolab System during January 1996.

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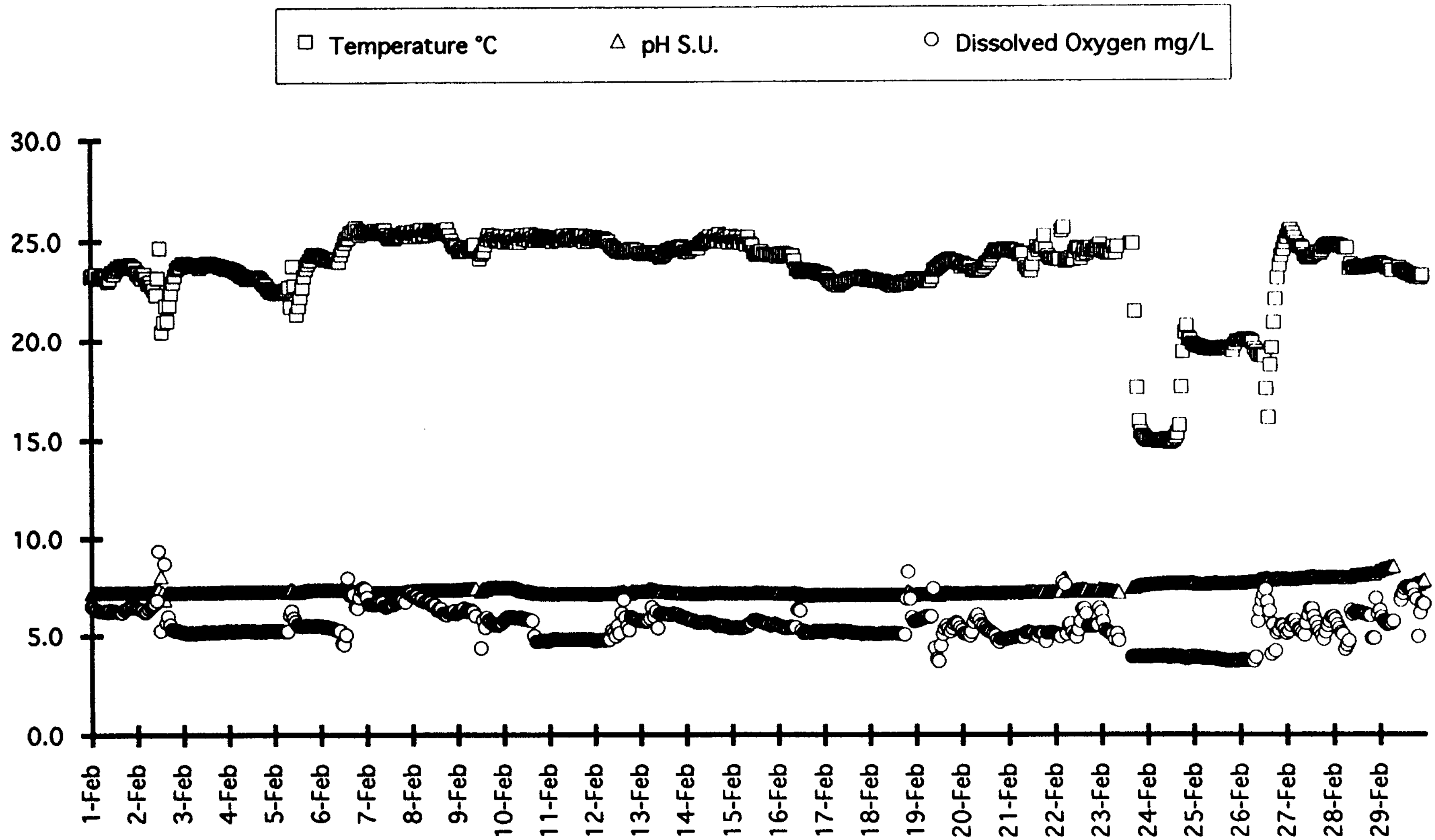

Figure 4-2.1q. GWTF effluent temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during February 1996.

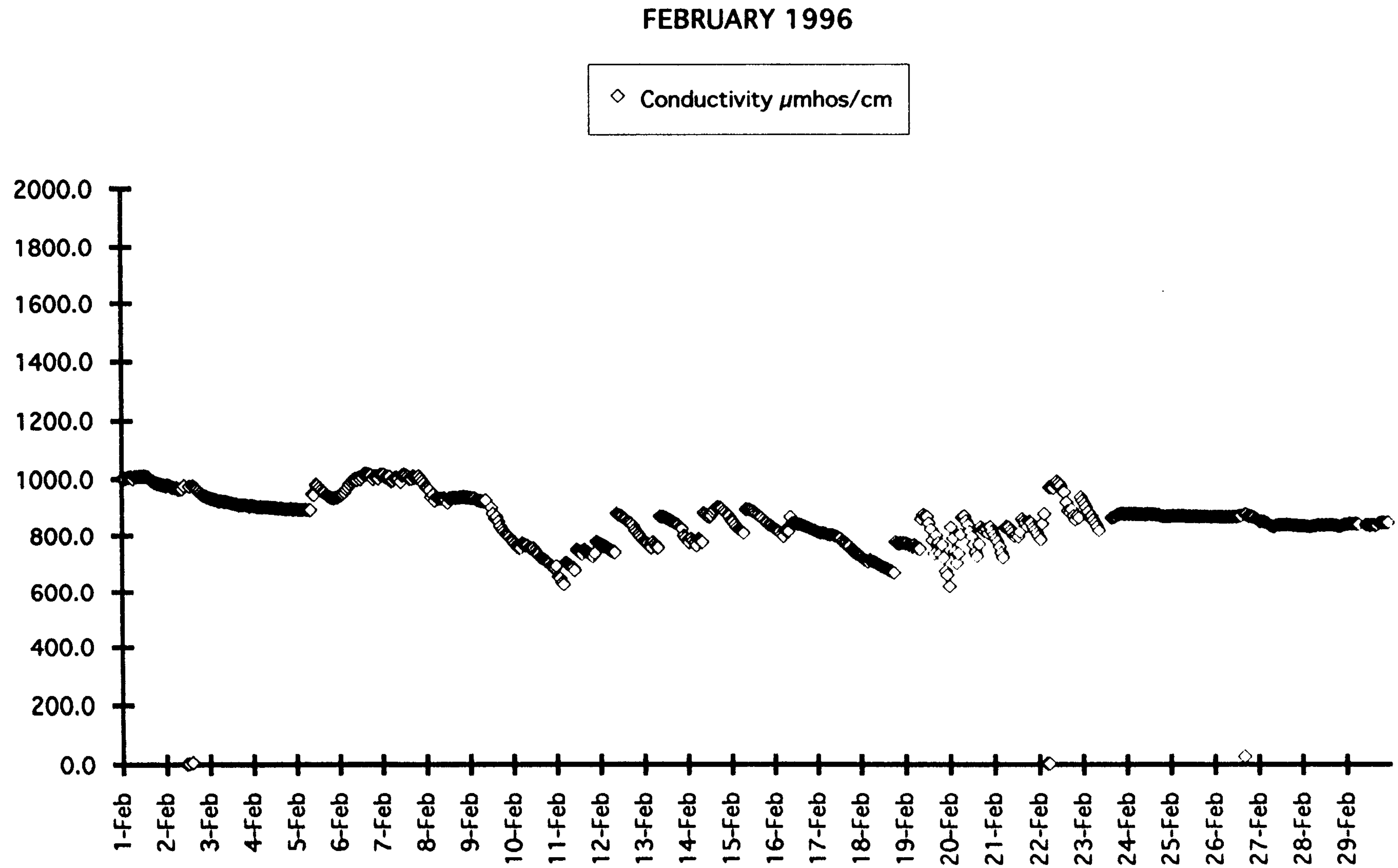

Figure 4-2.1r. GWTF effluent conductivity data obtained by the Hydrolab System during February 1996.

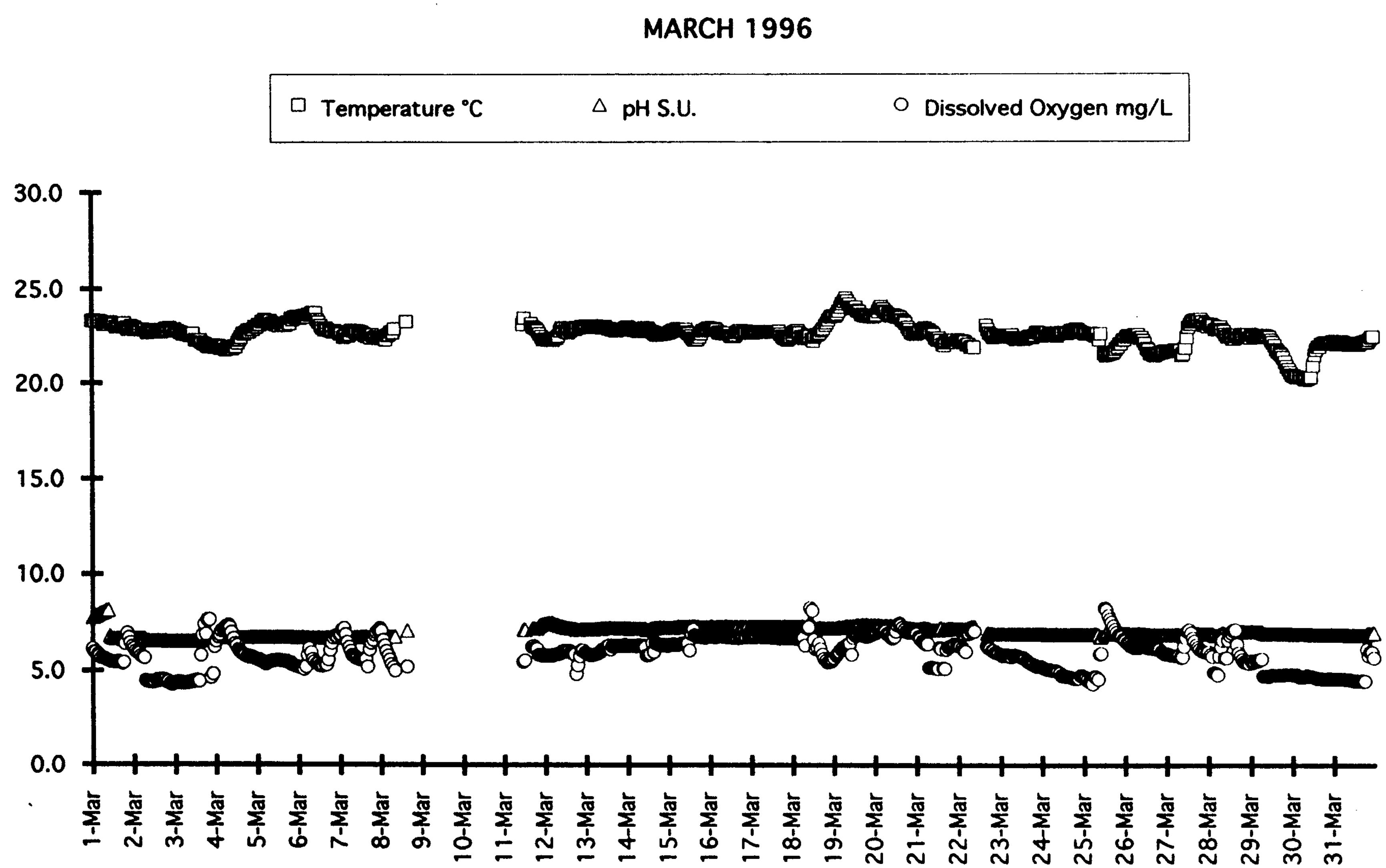

Figure 4-2.1s. GWTF effluent temperature, pH and dissolved oxygen data obtained by the Hydrolab System during March 1996.

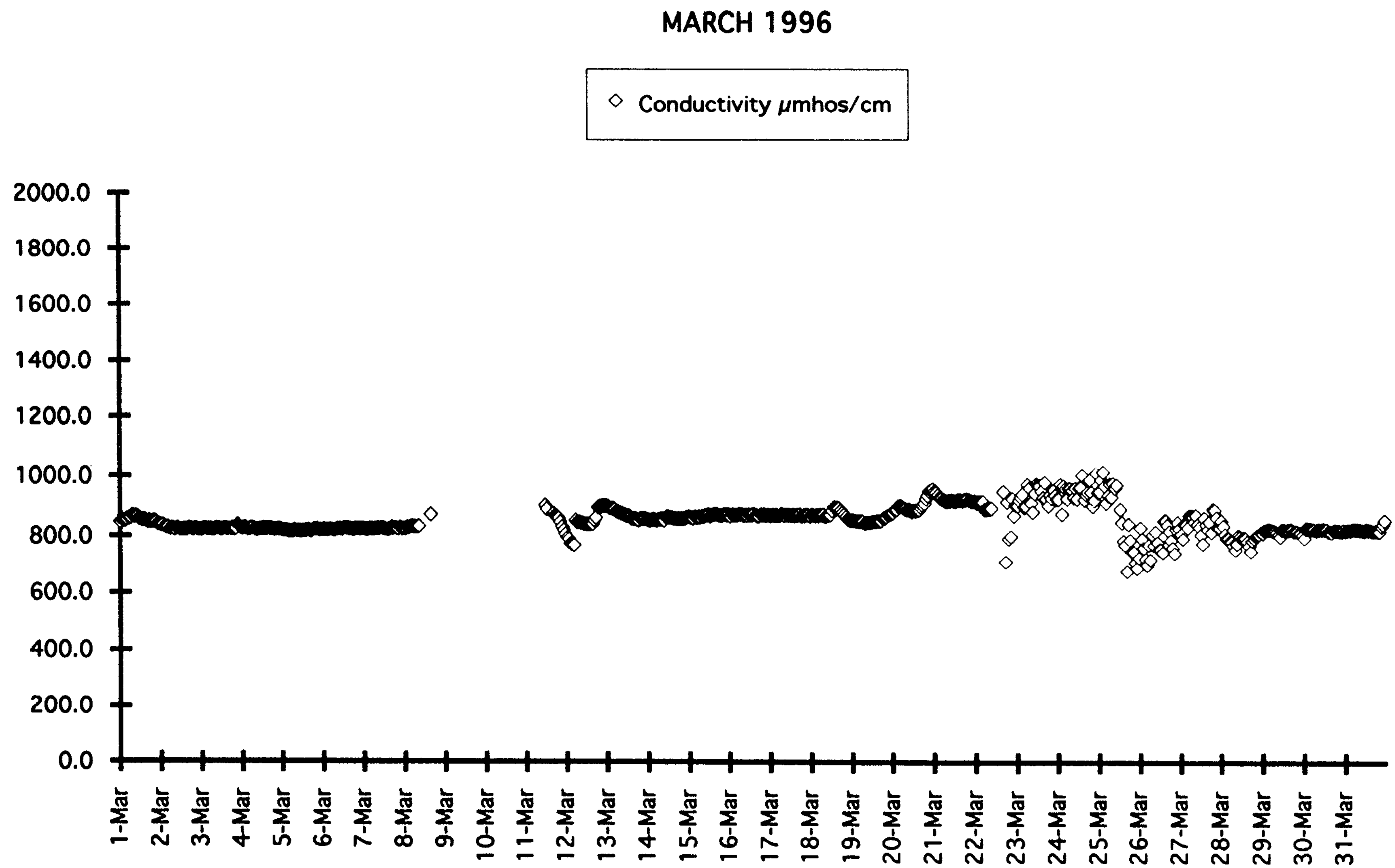

Figure 4-2.1t. GWTF effluent conductivity data obtained by the Hydrolab System during March 1996.

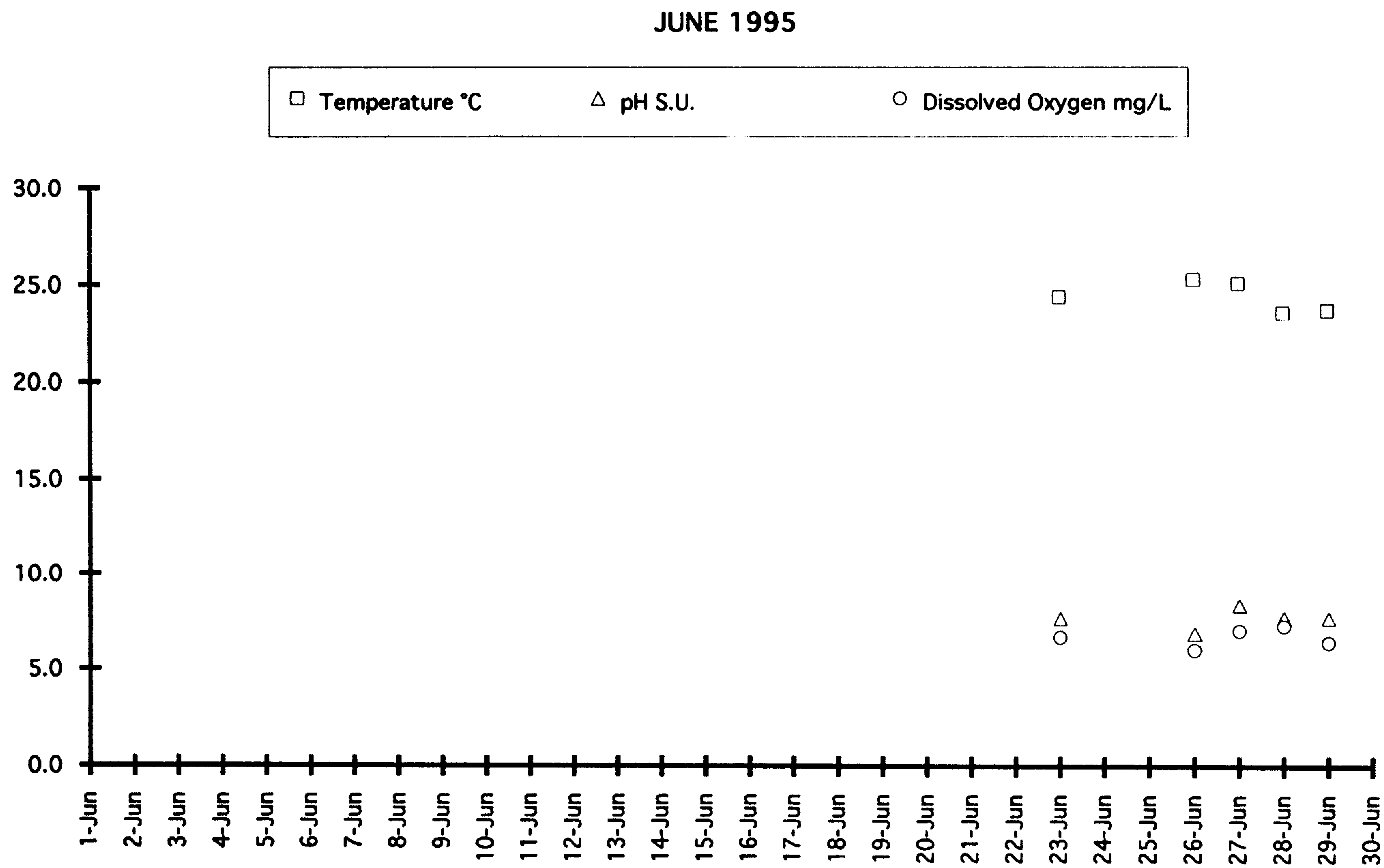

Figure 4-2.2a. GWTF effluent temperature, pH, and dissolved oxygen data obtained manually during June 1995.

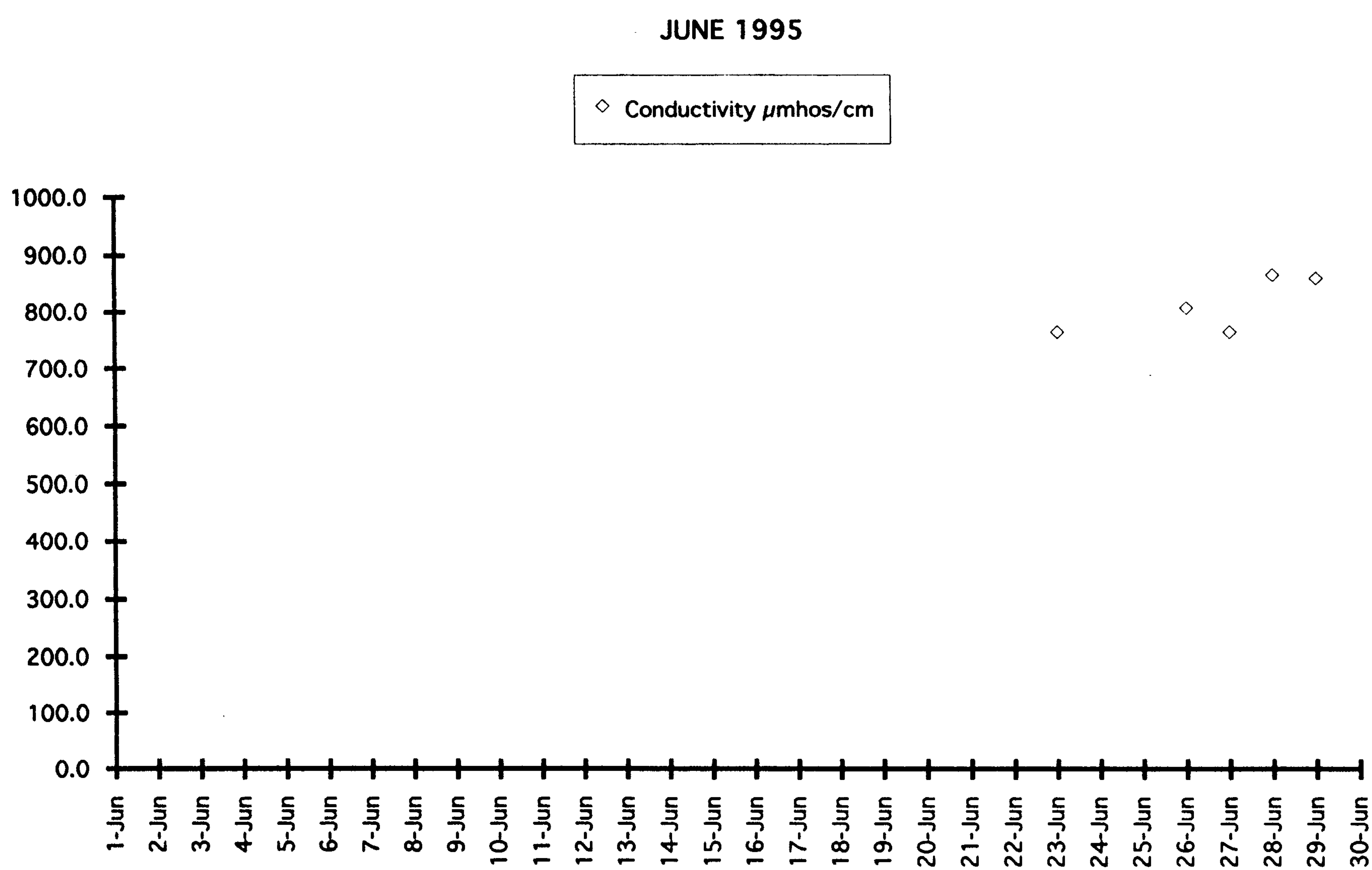

Figure 4-2.2b. GWTF effluent conductivity data obtained manually during June 1995.

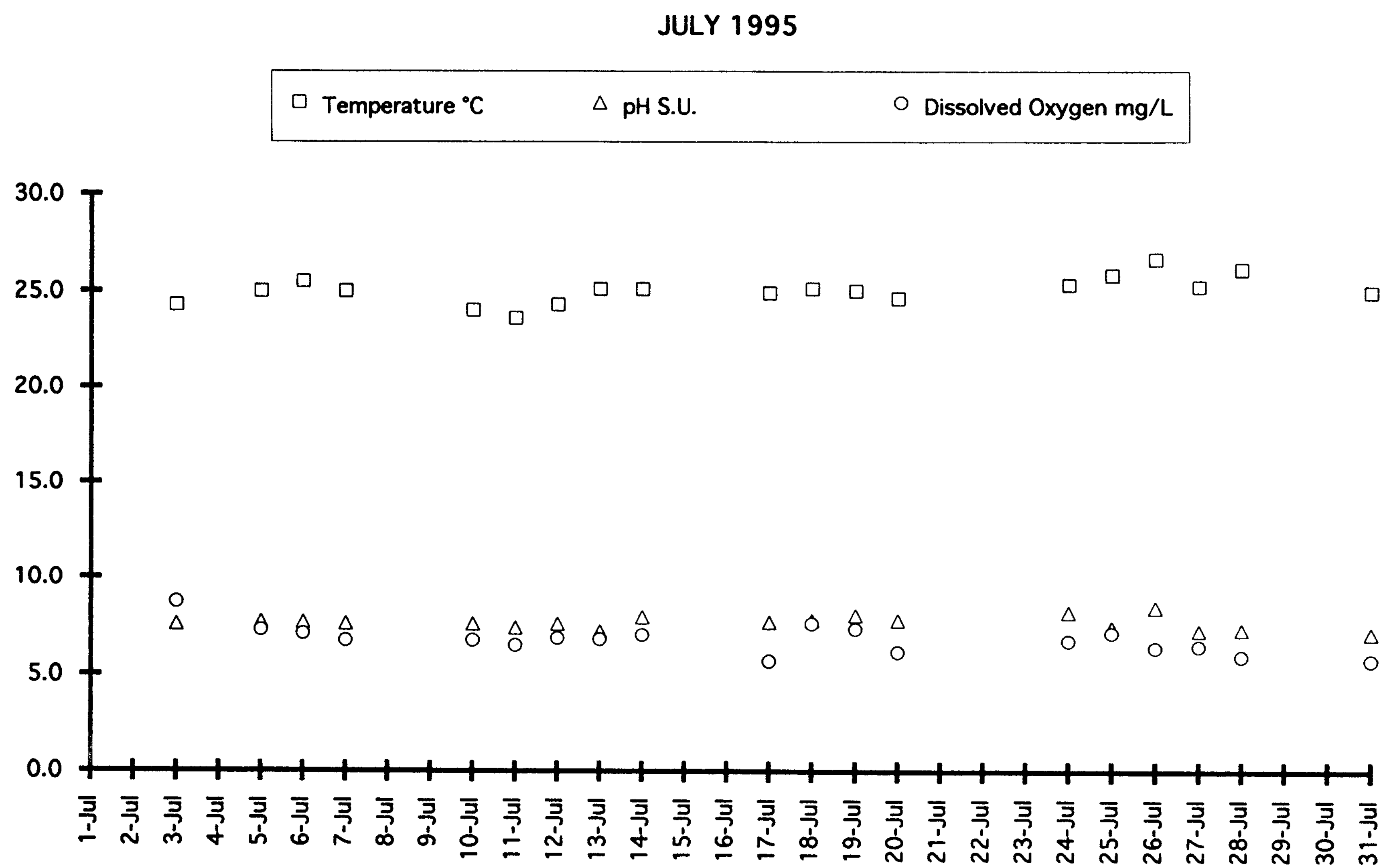

Figure 4-2.2c. GWTF effluent temperature, pH, and dissolved oxygen data obtained manually during July 1995.

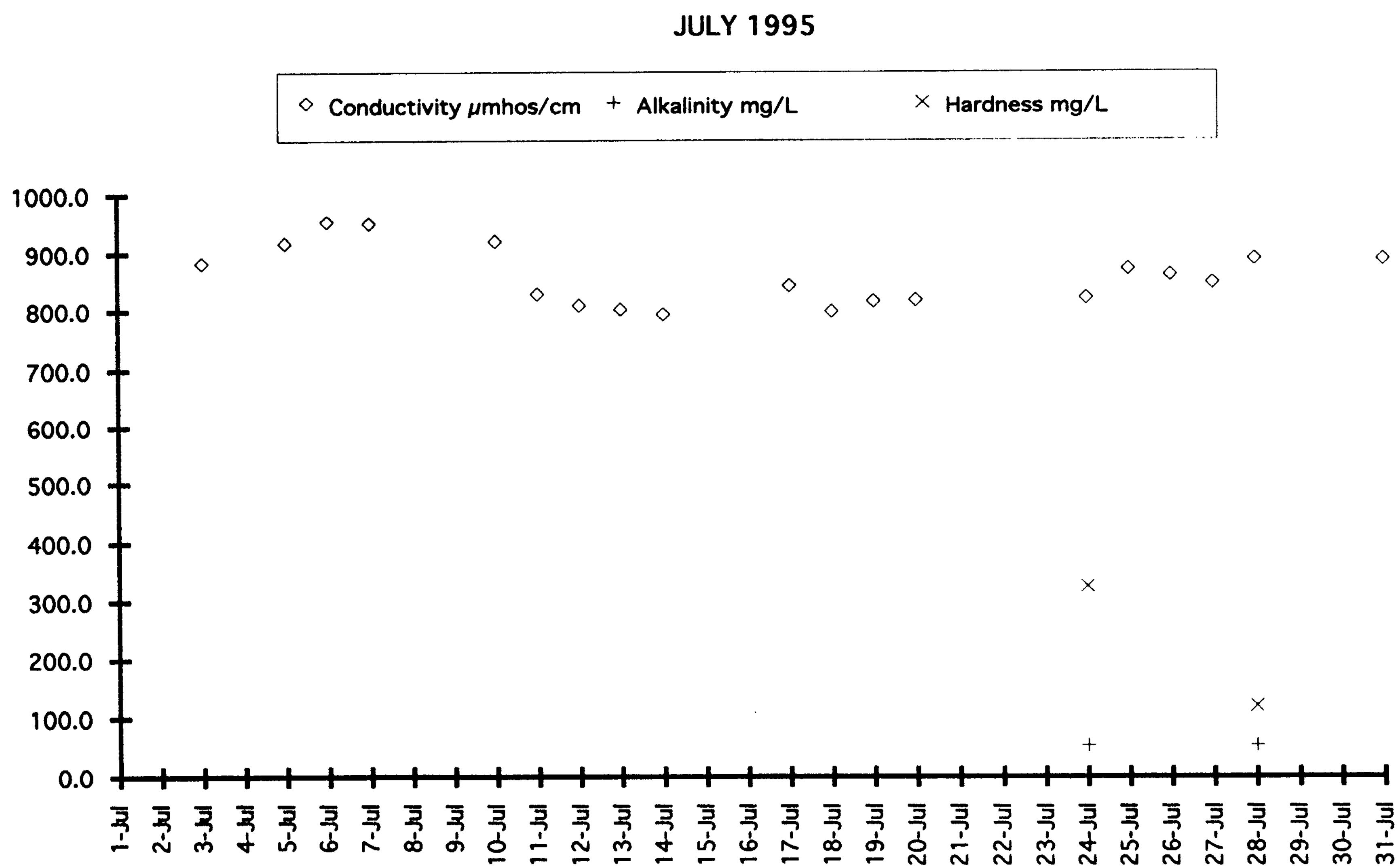

Figure 4-2.2d. GWTF effluent conductivity, alkalinity, and hardness data obtained manually during July 1995.

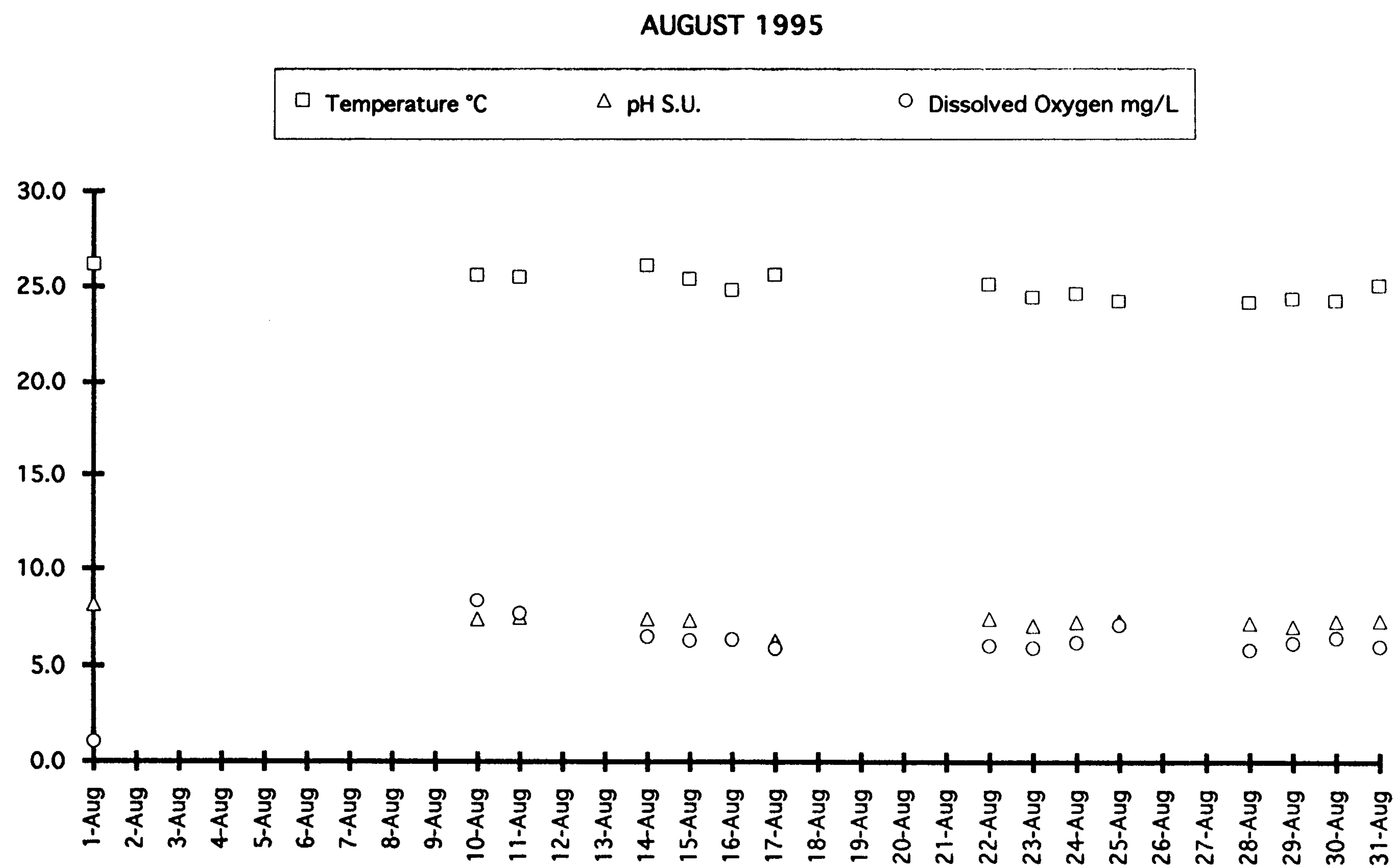

Figure 4-2.2e. GWTF effluent water temperature, pH, and dissolved oxygen data obtained manually during August 1995.

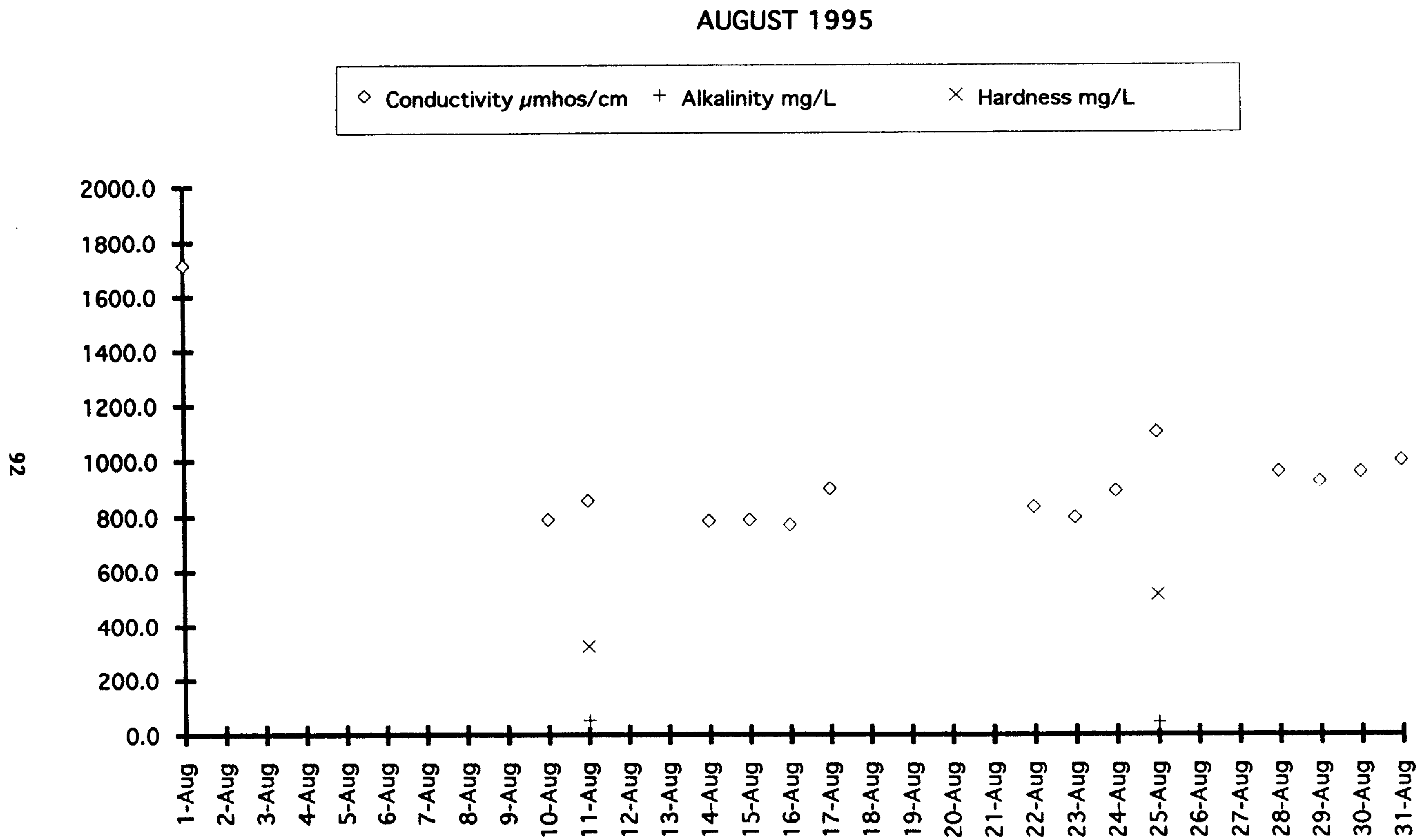

Figure 4-2.2f. GWTF effluent conductivity, alkalinity, and hardness data obtained manually during August 1995.

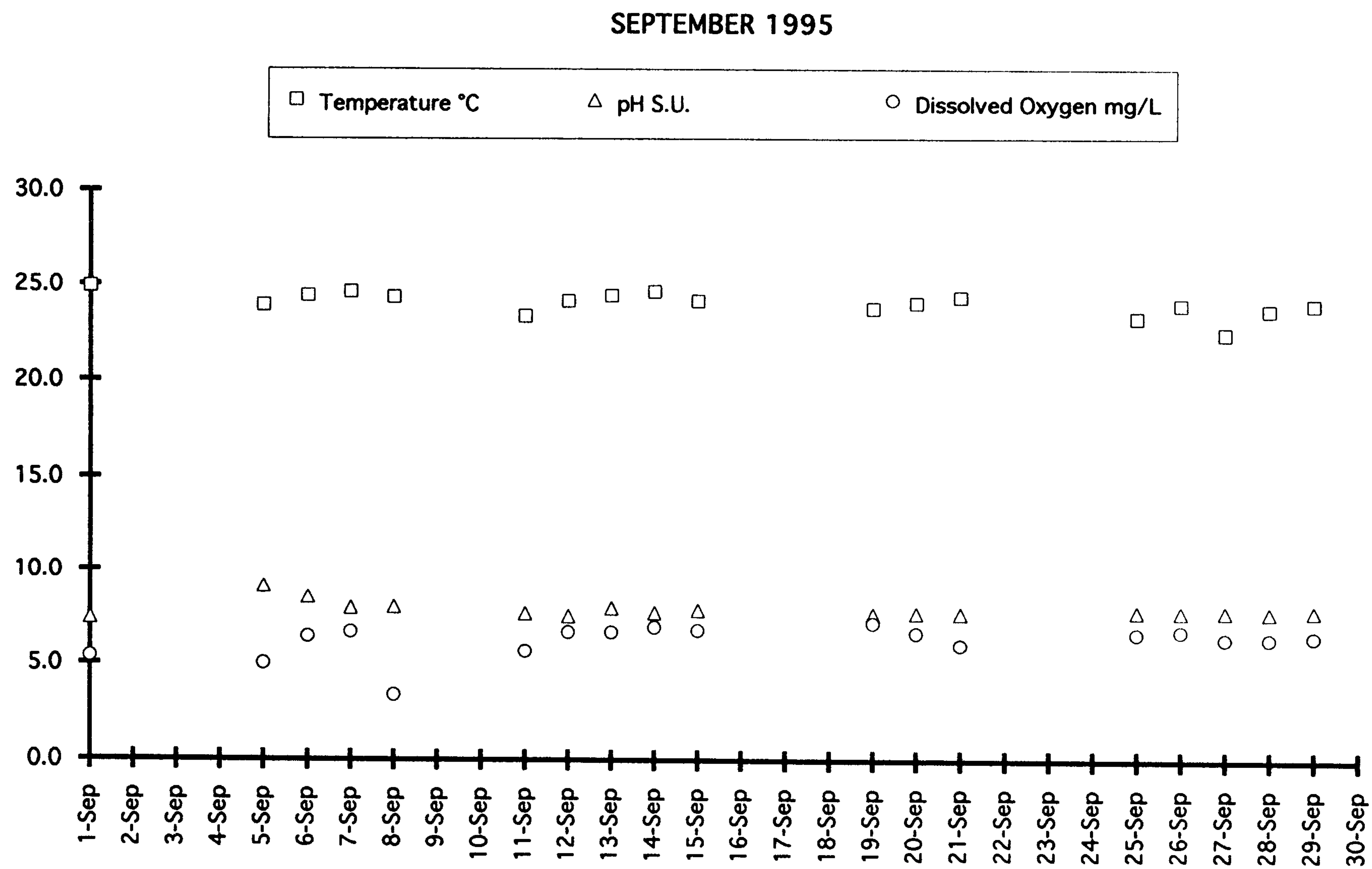

Figure 4-2.2g. GWTF effluent temperature, pH, and dissolved oxygen data obtained manually during September 1995.

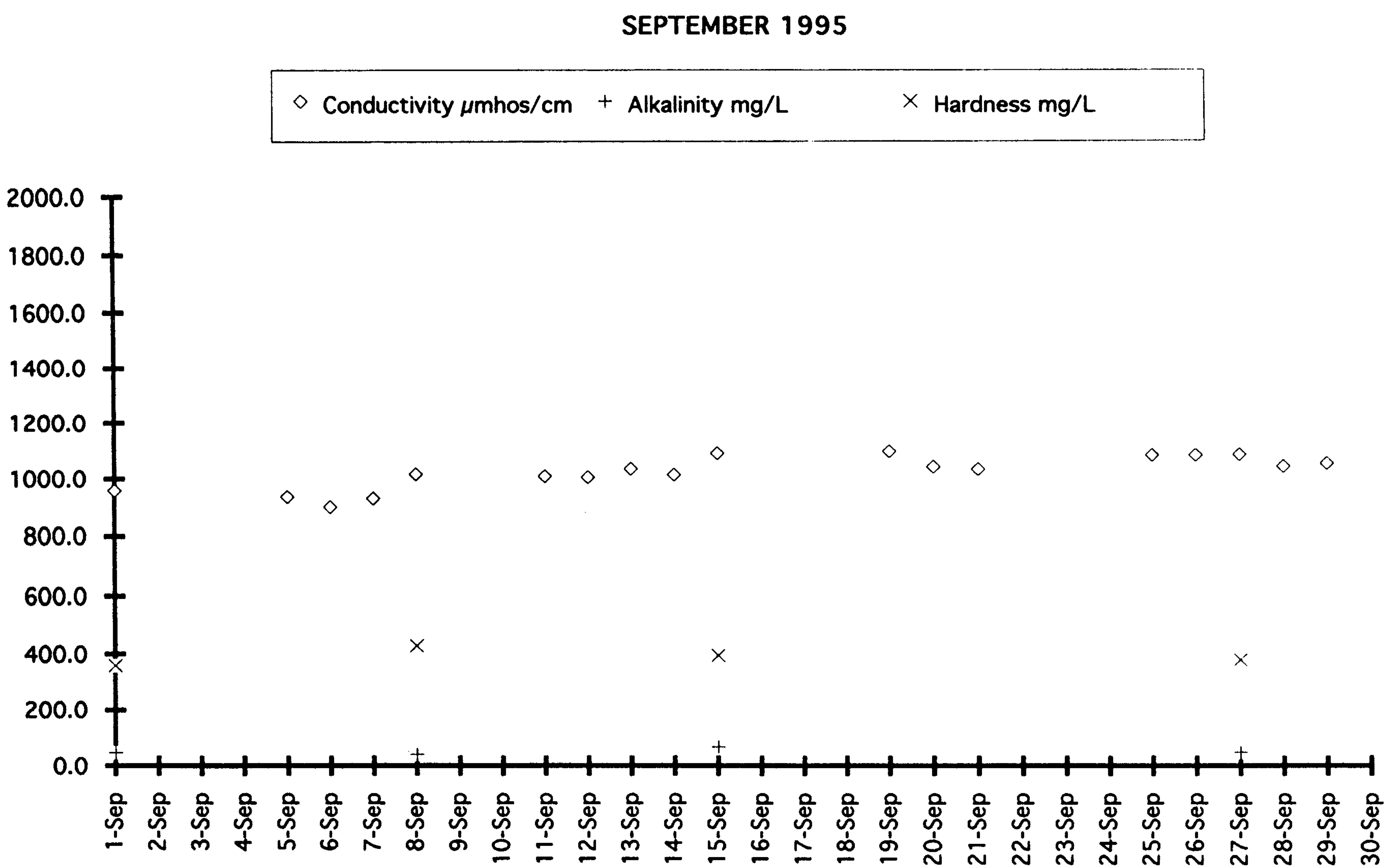

Figure 4-2.2h. GWTF effluent conductivity, alkalinity, and hardness data obtained manually during September 1995.

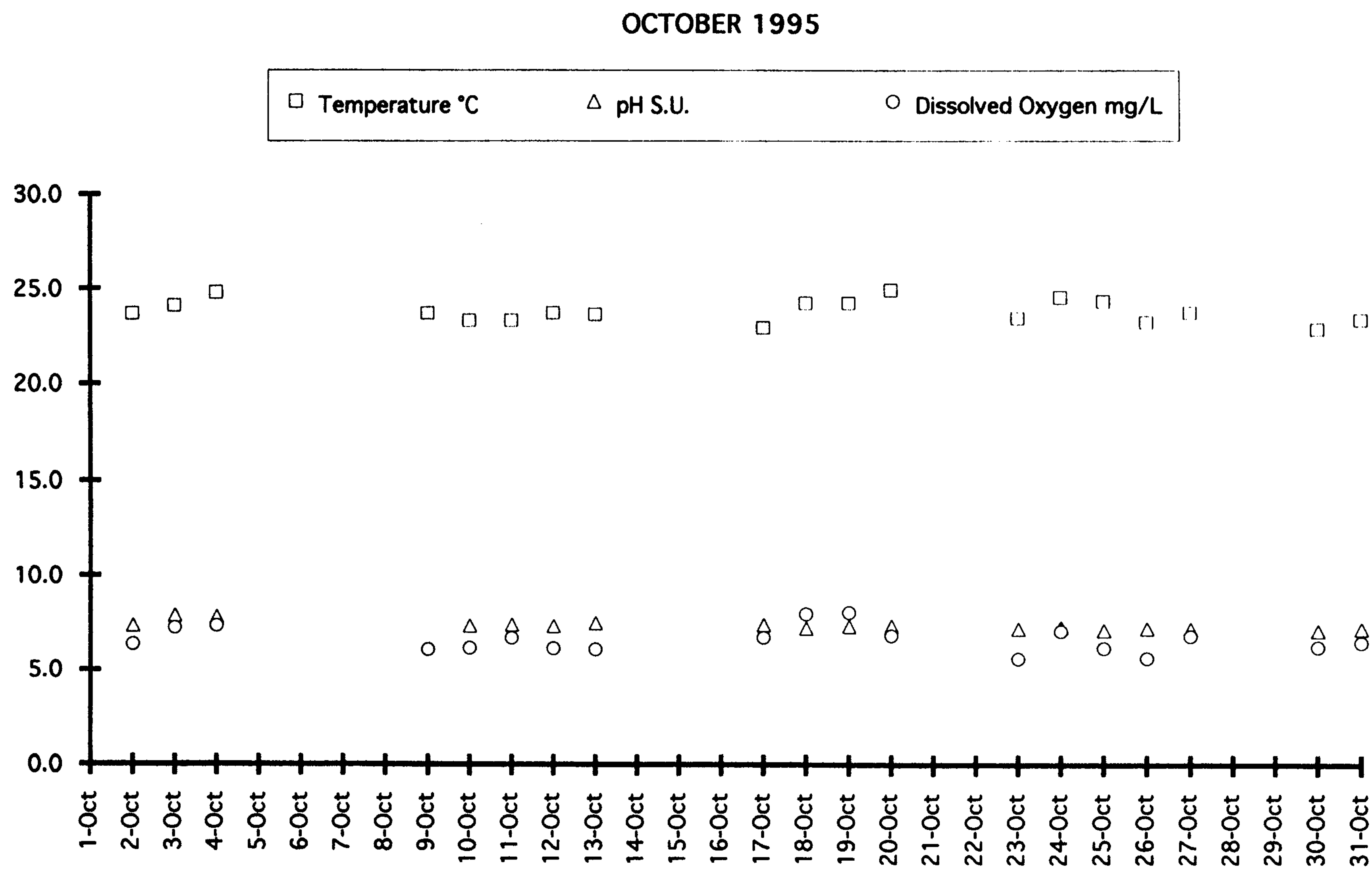

Figure 4-2.2i. GWTF effluent temperature, pH, and dissolved oxygen data obtained manually during October 1995.

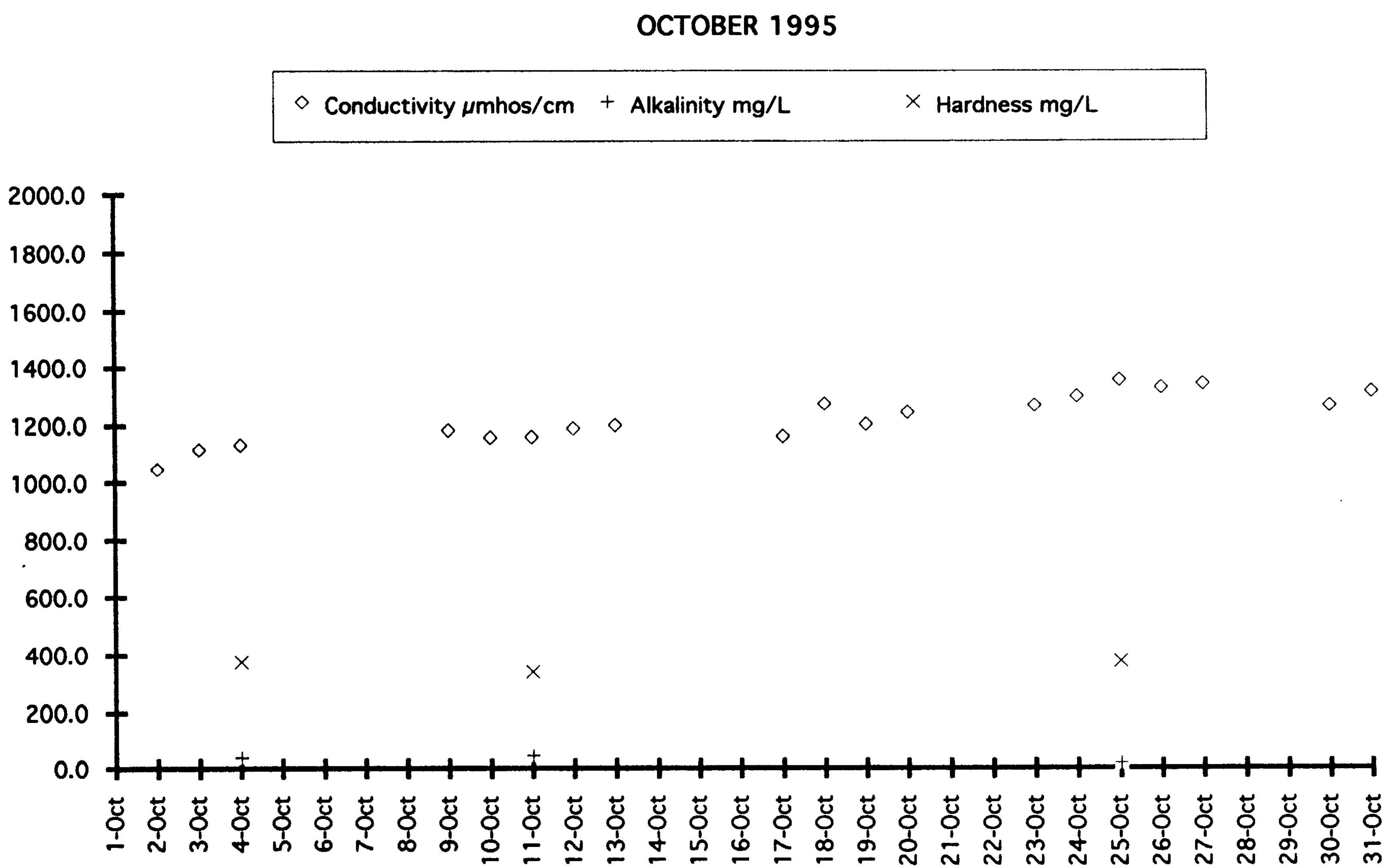

Figure 4-2.2j. GWTF effluent conductivity, alkalinity, and hardness data obtained manually during October 1995.

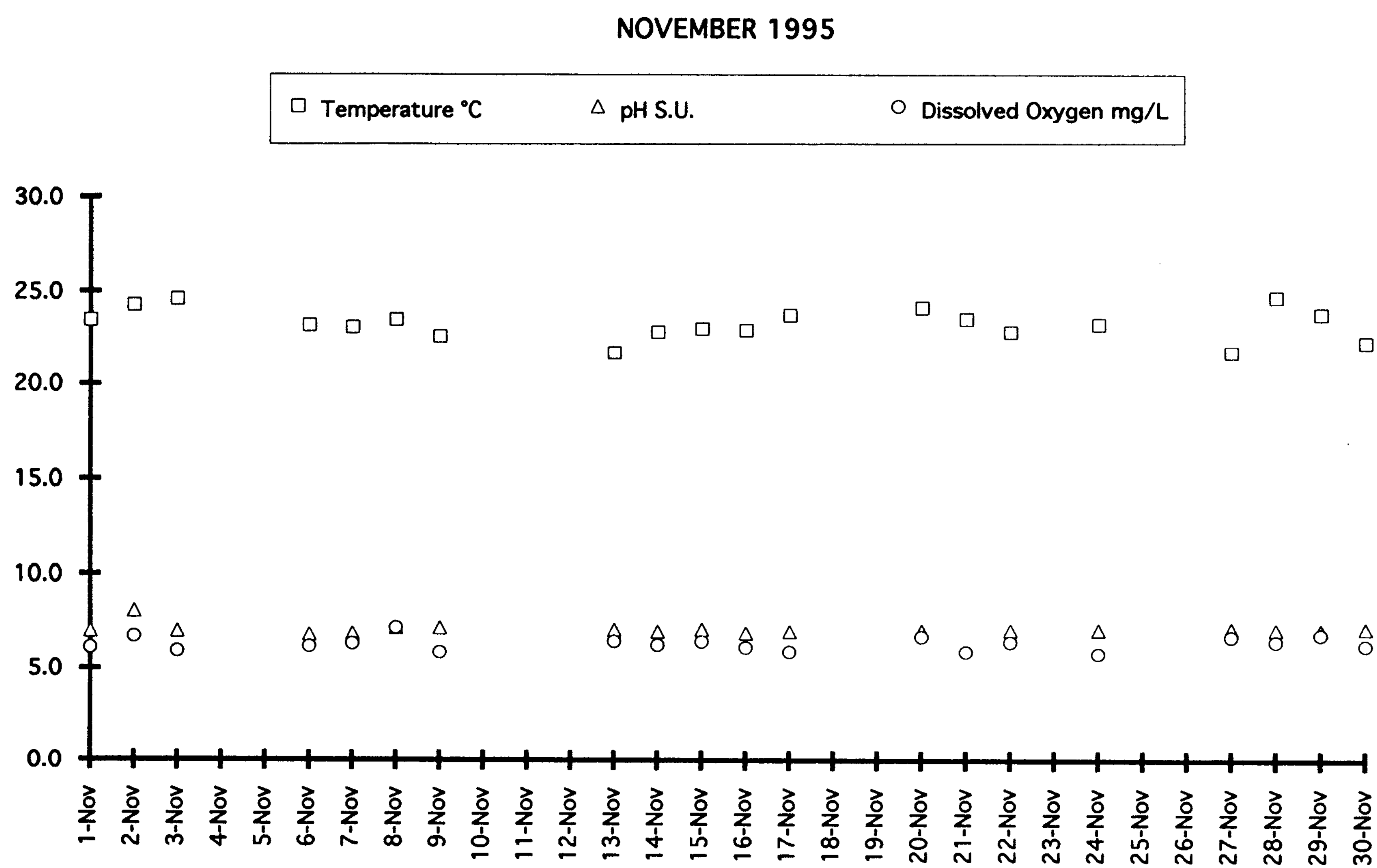

Figure 4-2.2k. GWTF effluent temperature, pH, and dissolved oxygen data obtained manually during November 1995.

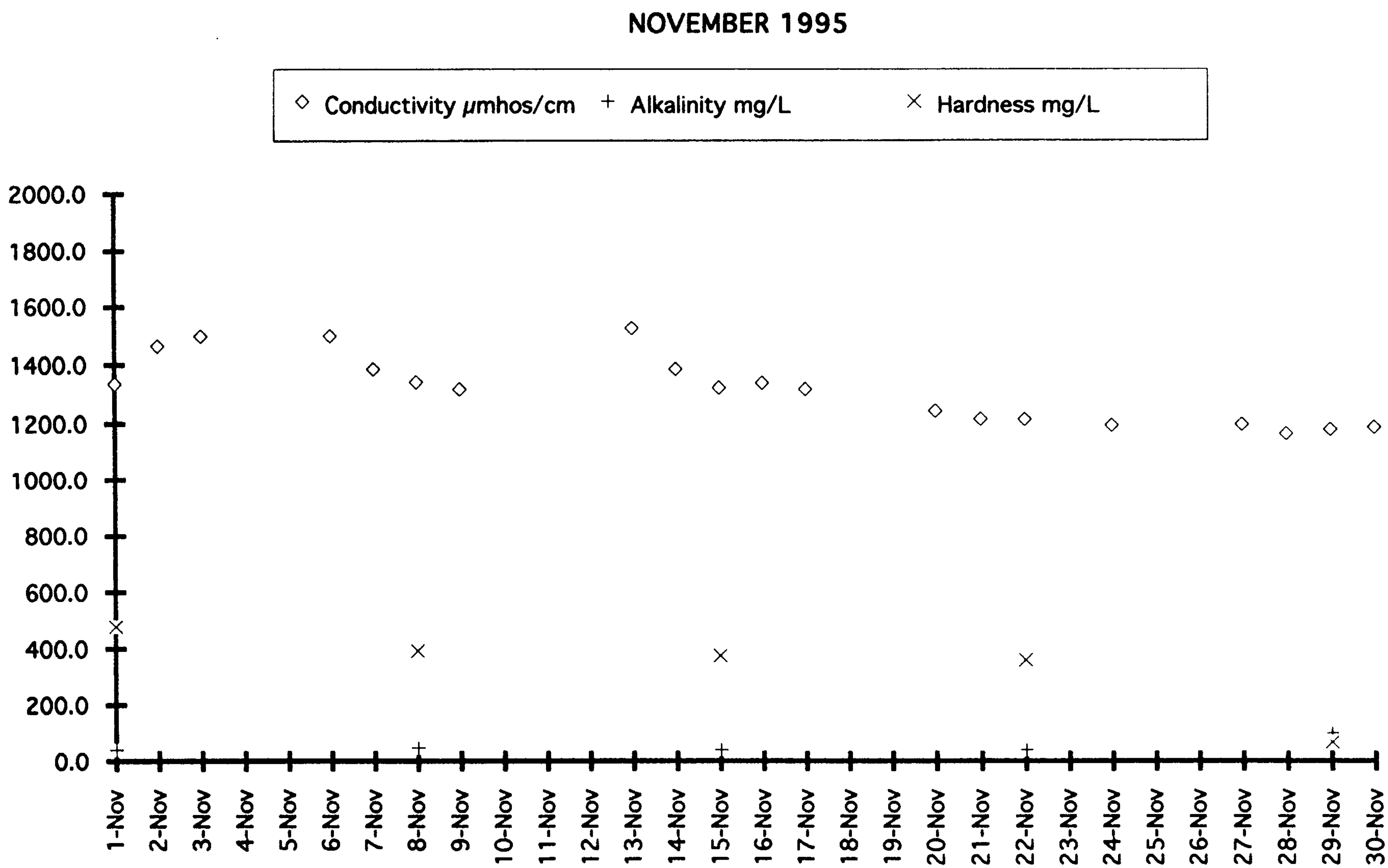

Figure 4-2.2l. GWTF effluent conductivity, alkalinity, and hardness data obtained manually during November 1995.

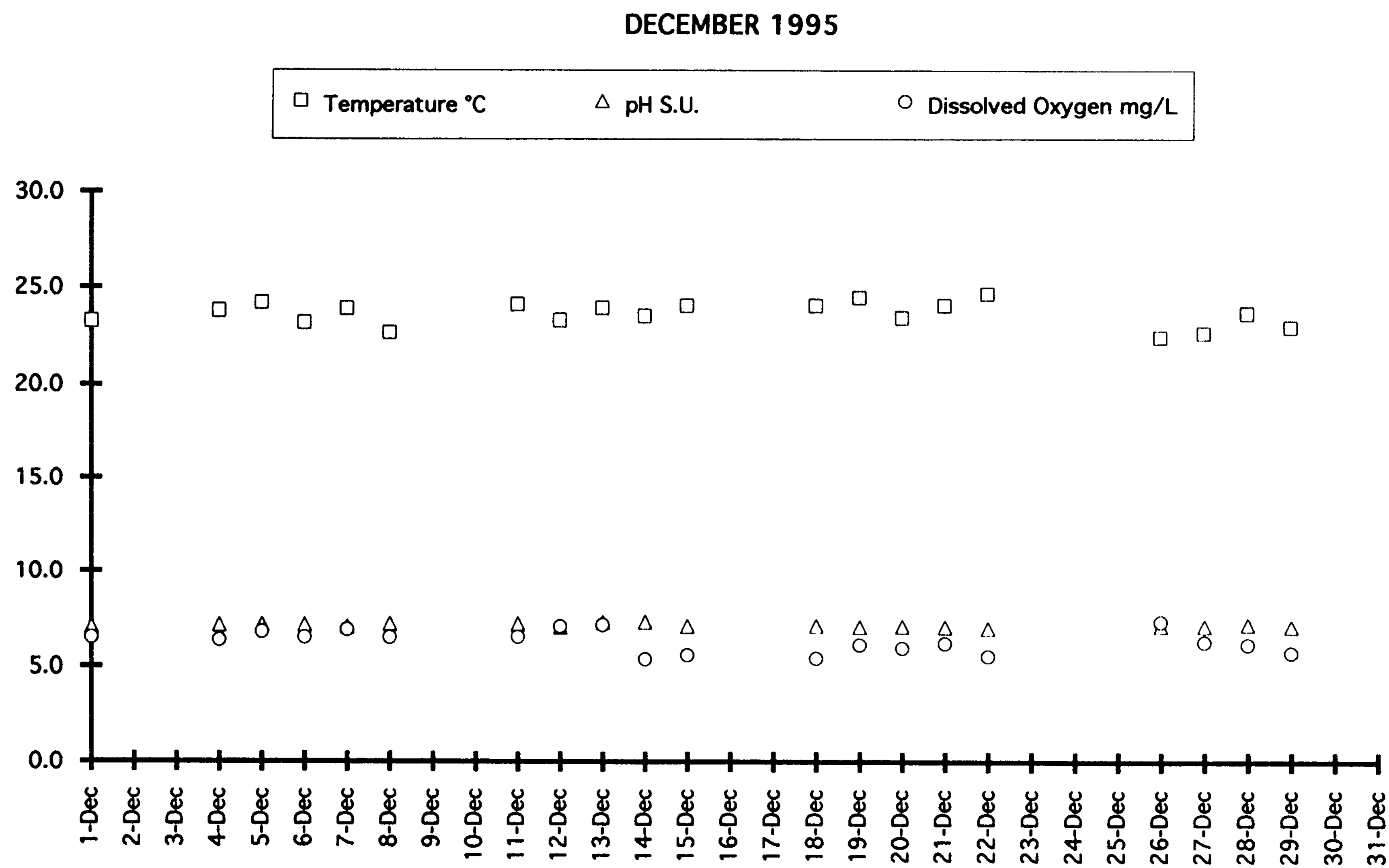

Figure 4-2.2m. GWTF effluent temperature, pH, and dissolved oxygen data obtained manually during December 1995.

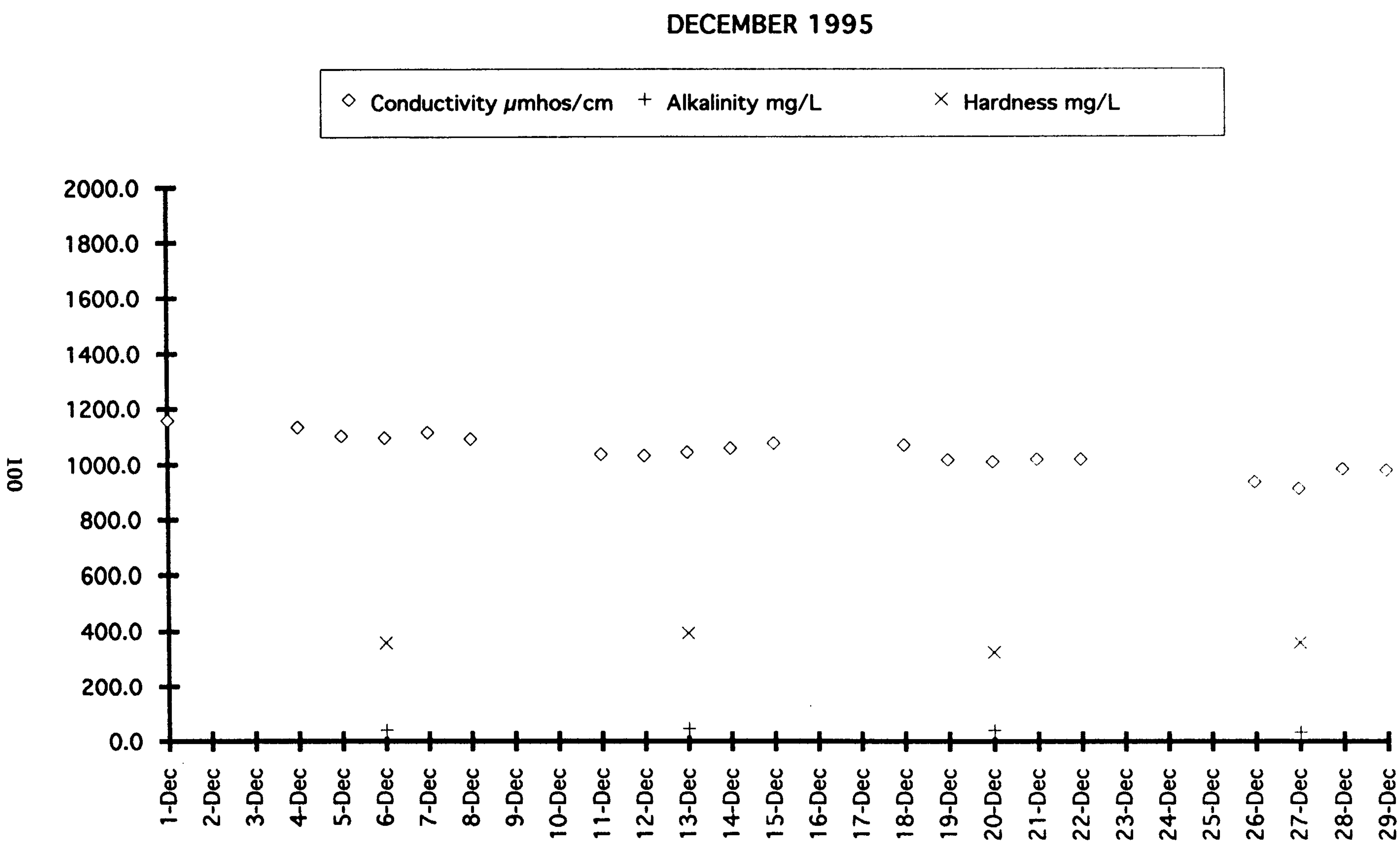

Figure 4-2.2n. GWTF effluent conductivity, alkalinity, and hardness data obtained manually during December 1995.

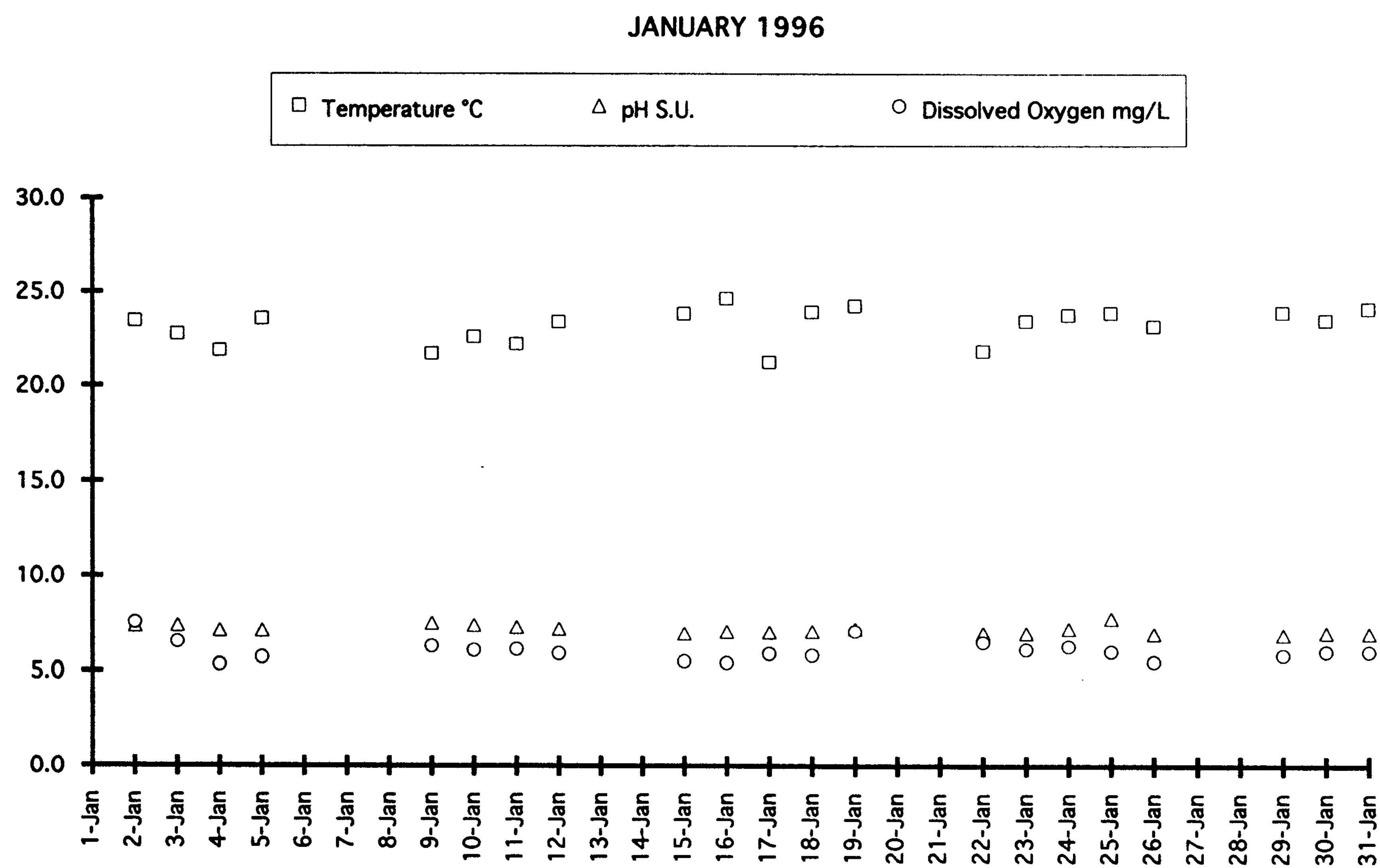

Figure 4-2.2o. GWTF effluent temperature, pH, and dissolved oxygen data obtained manually during January 1996.

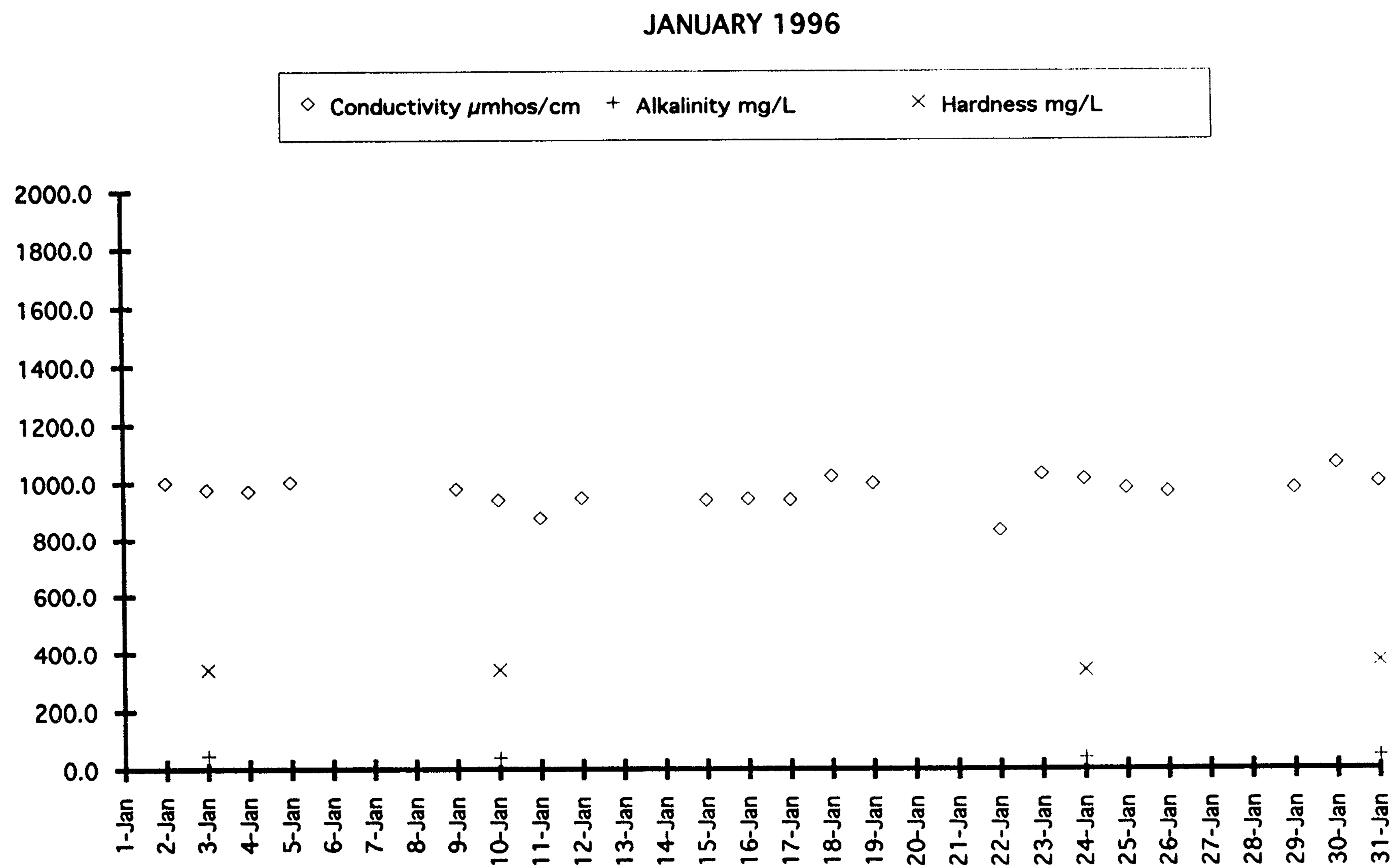

Figure 4-2.2p. GWTF effluent conductivity, alkalinity, and hardness data obtained manually during January 1996.

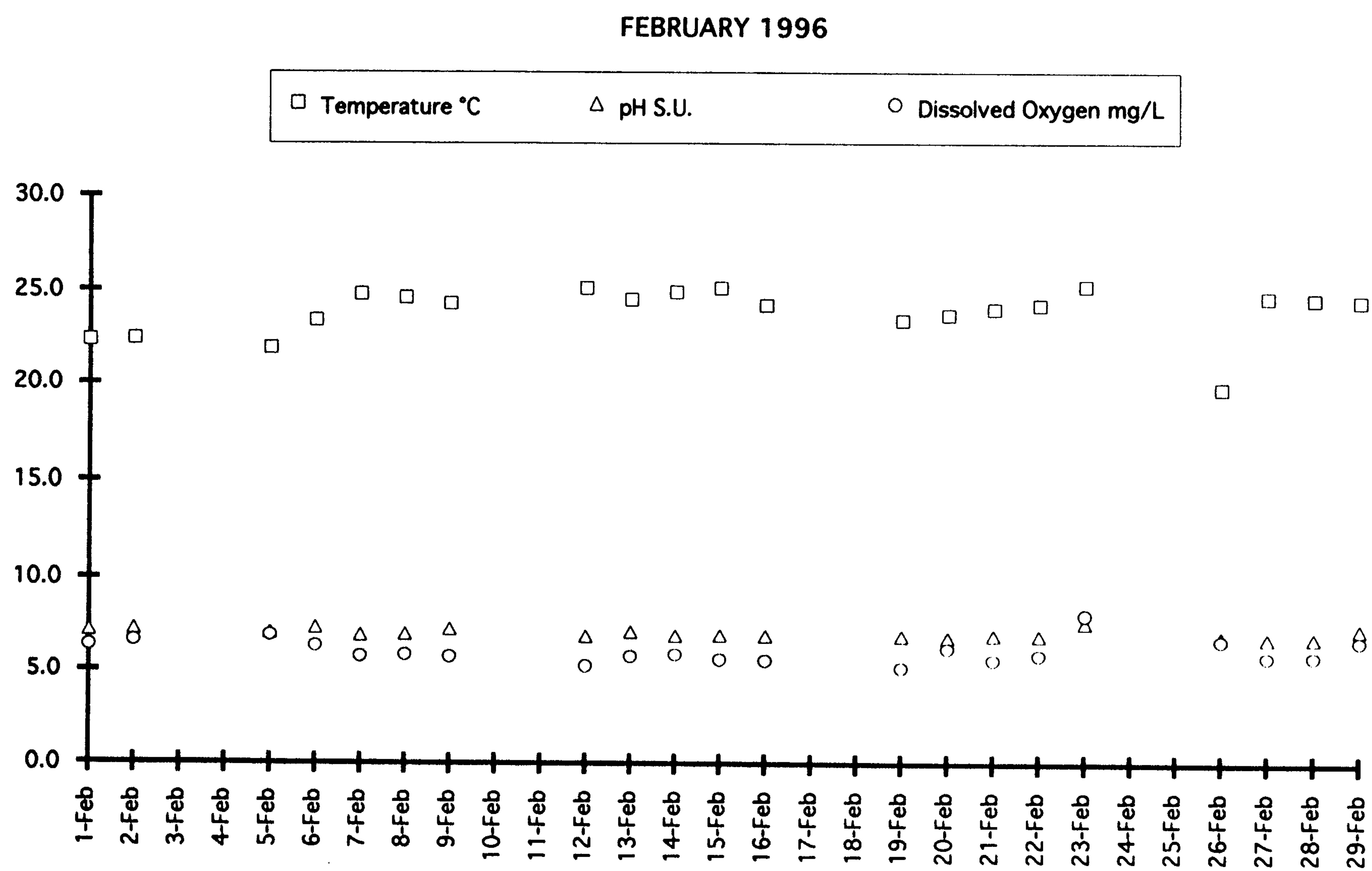

Figure 4-2.2q. GWTF effluent temperature, pH, and dissolved oxygen data obtained manually during February 1996.

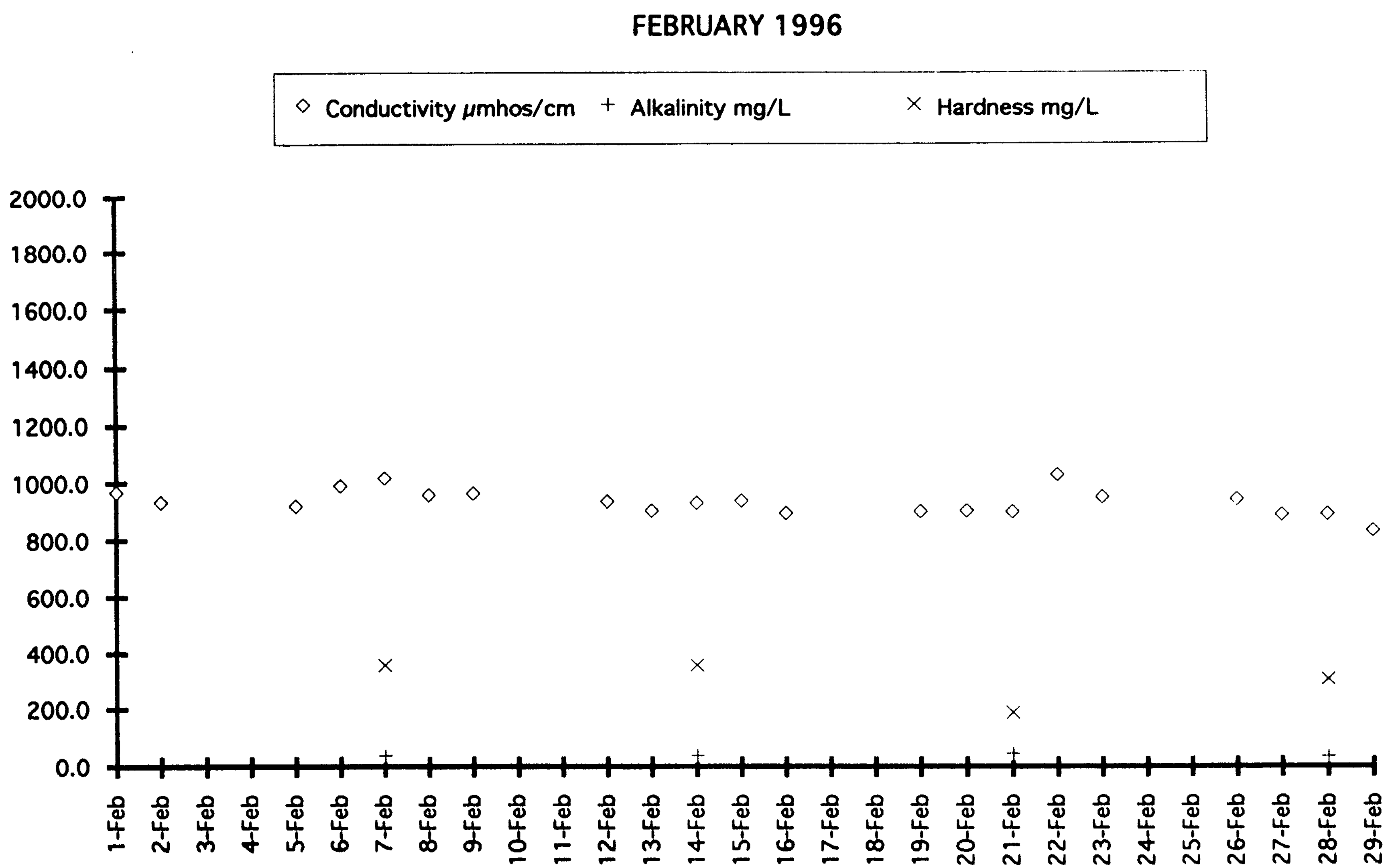

Figure 4-2.2r. GWTF effluent conductivity, alkalinity, and hardness data obtained manually during February 1996.

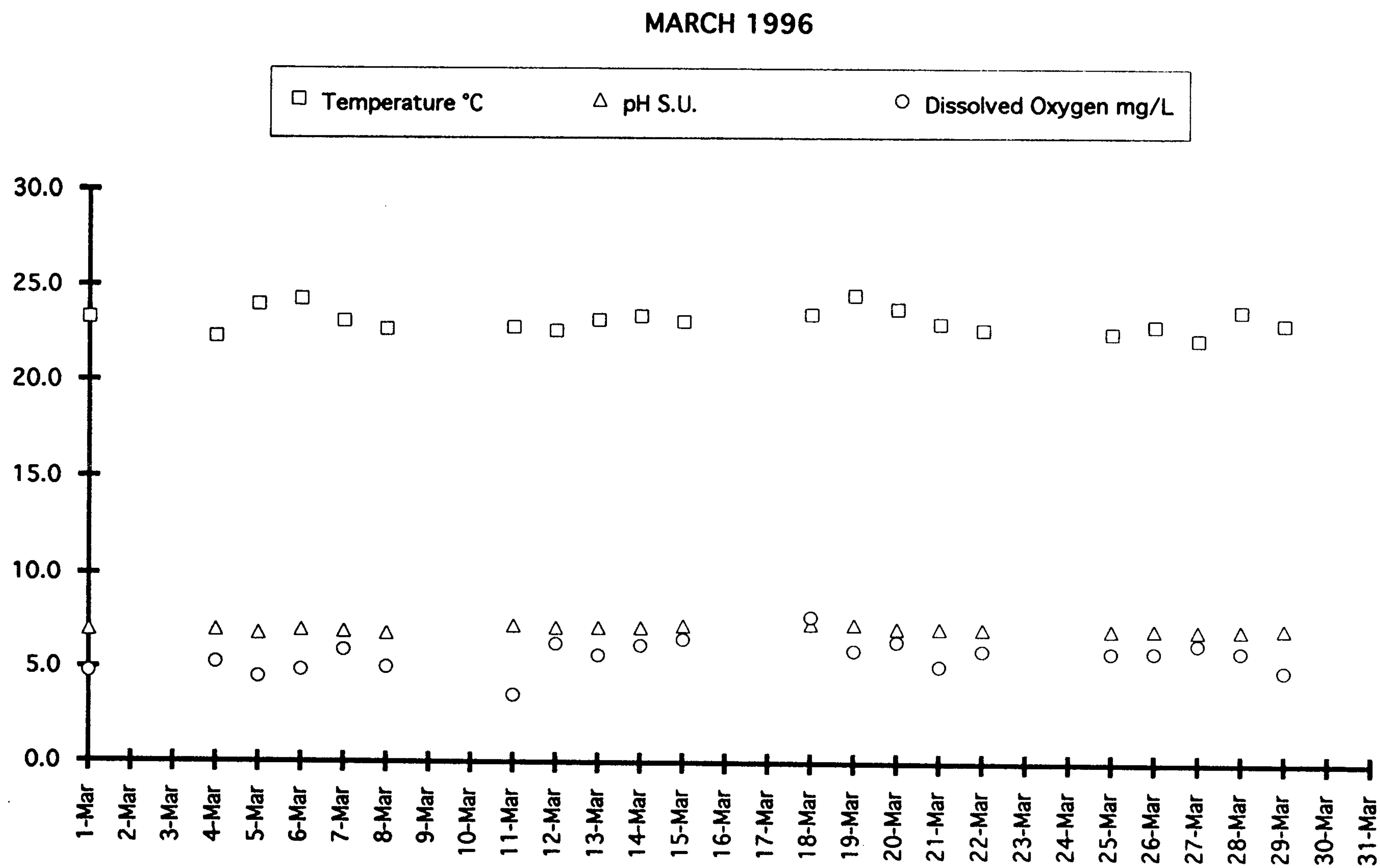

Figure 4-2.2s. GWTF effluent temperature, pH, and dissolved oxygen data obtained manually during March 1996.

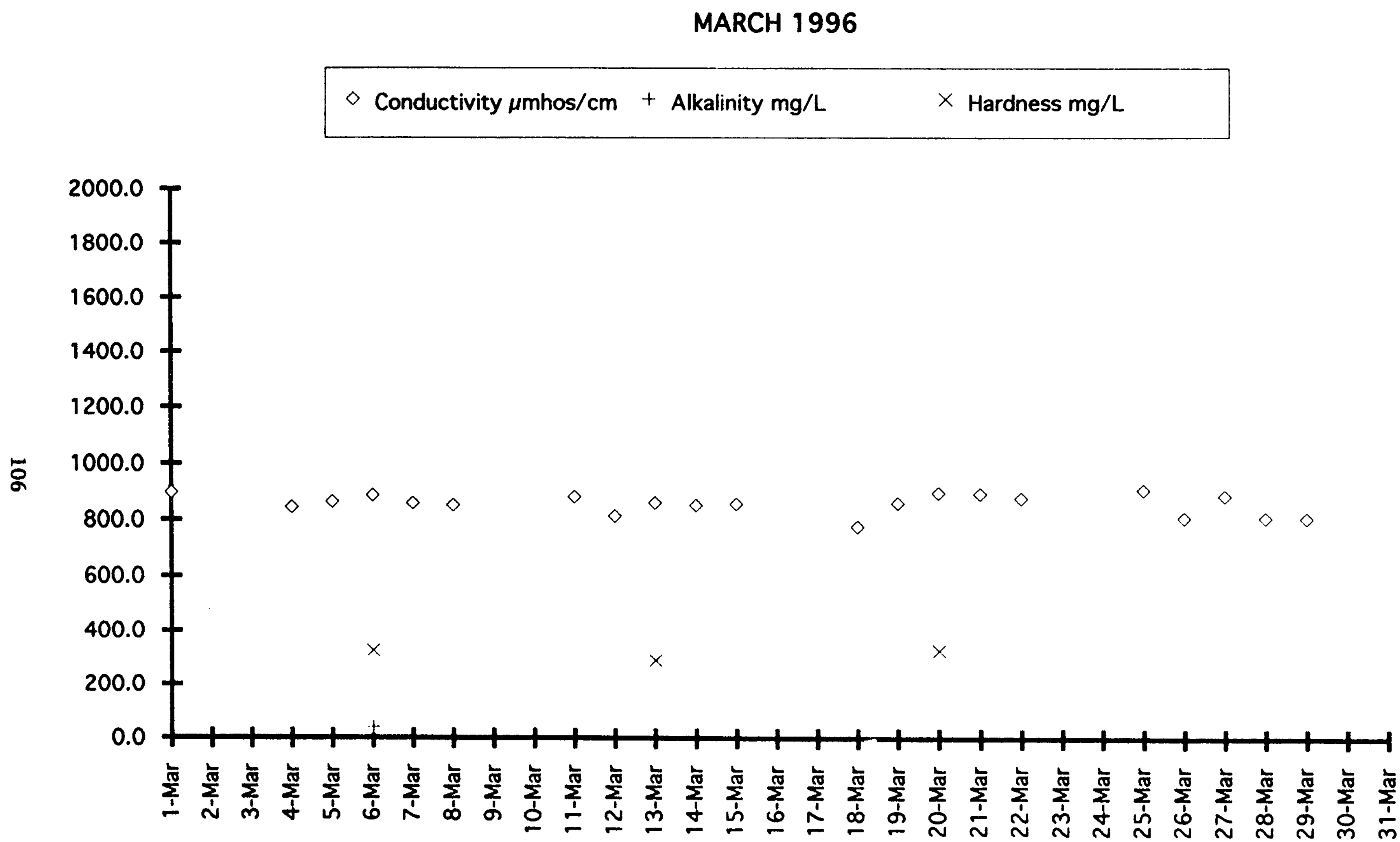

Figure 4-2.2t. GWTF effluent conductivity, alkalinity, and hardness data obtained manually during March 1996.

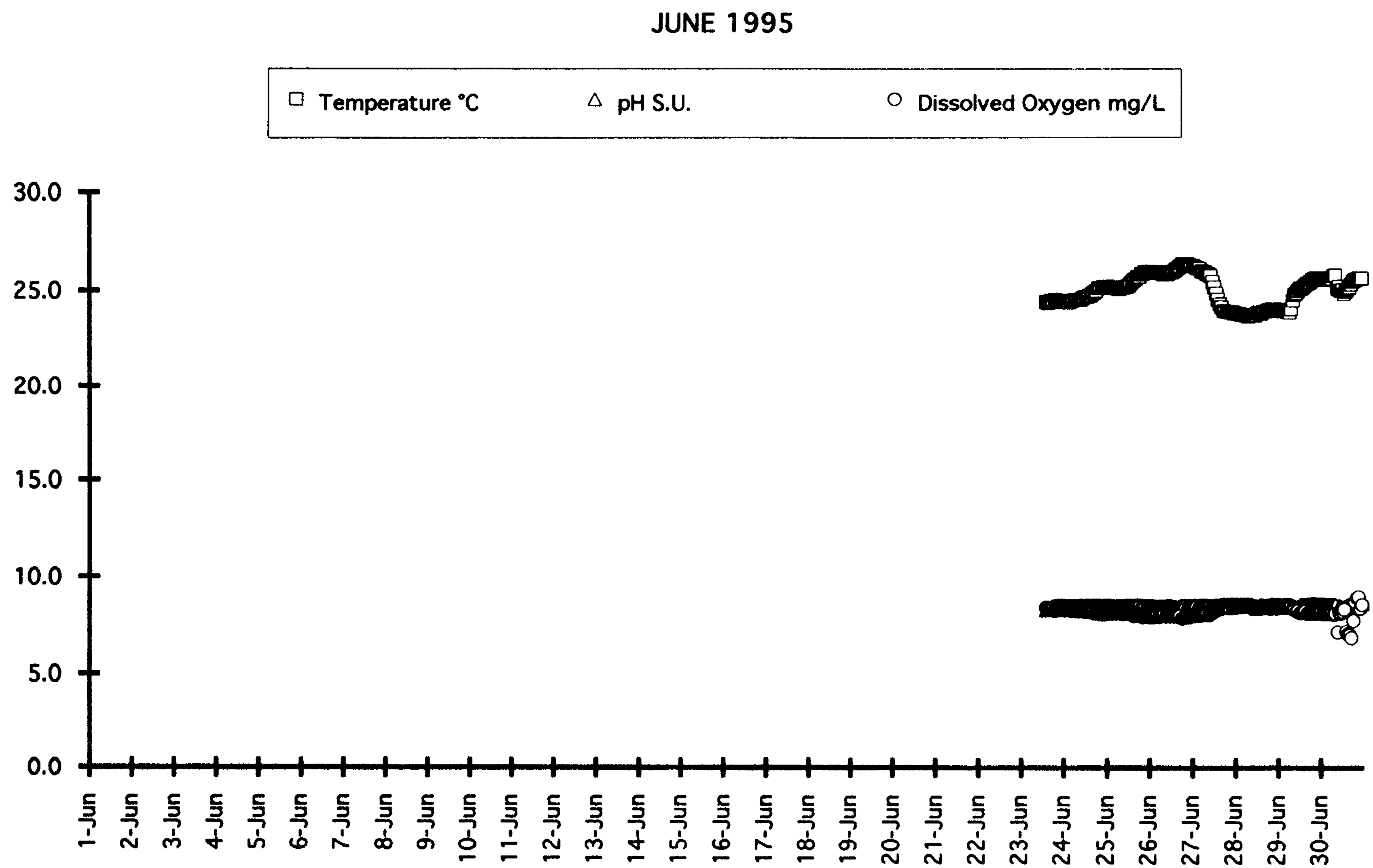

Figure 4-2.3a. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during June 1995.

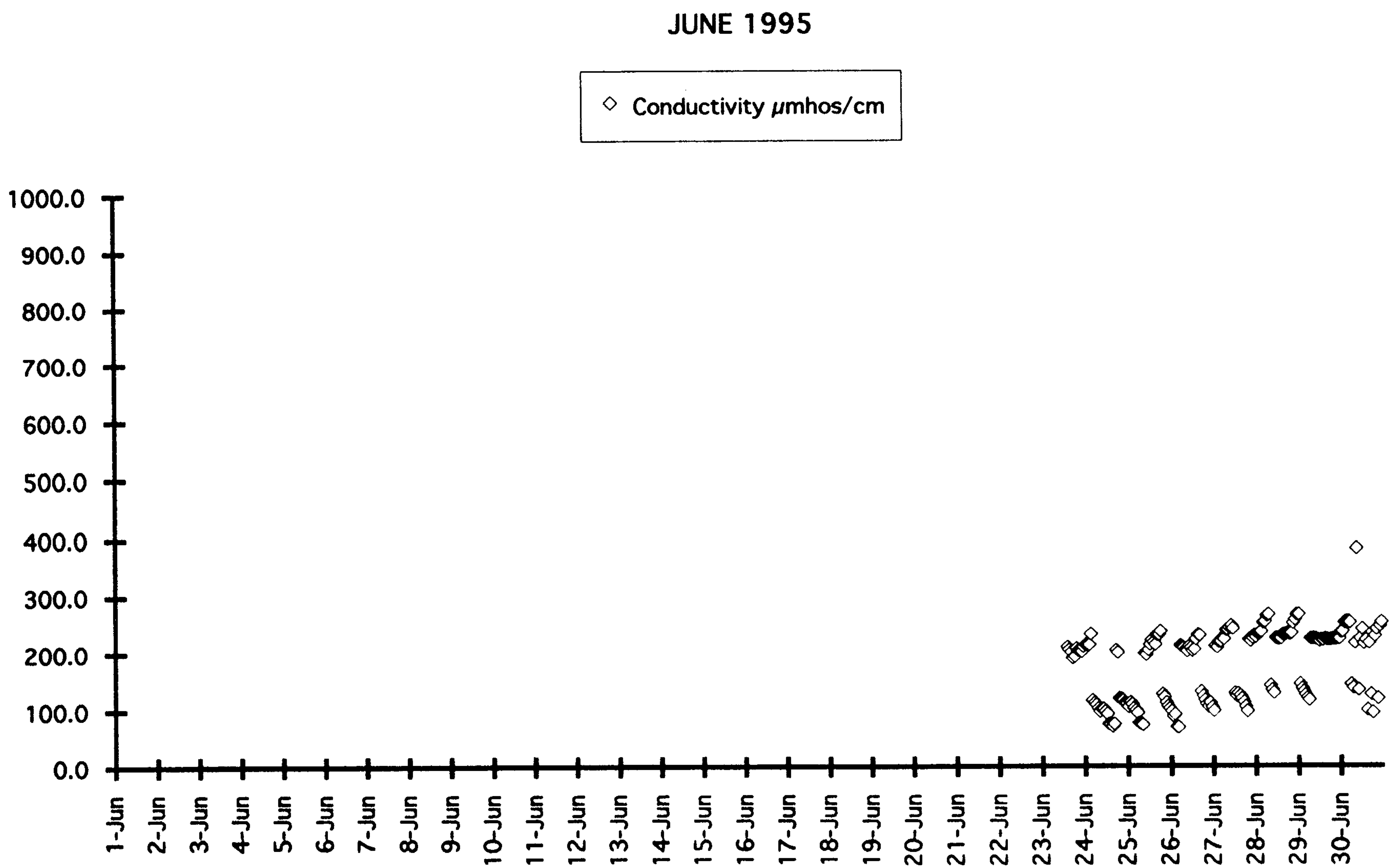

Figure 4-2.3b. Control water conductivity data obtained by the Hydrolab System during June 1995.

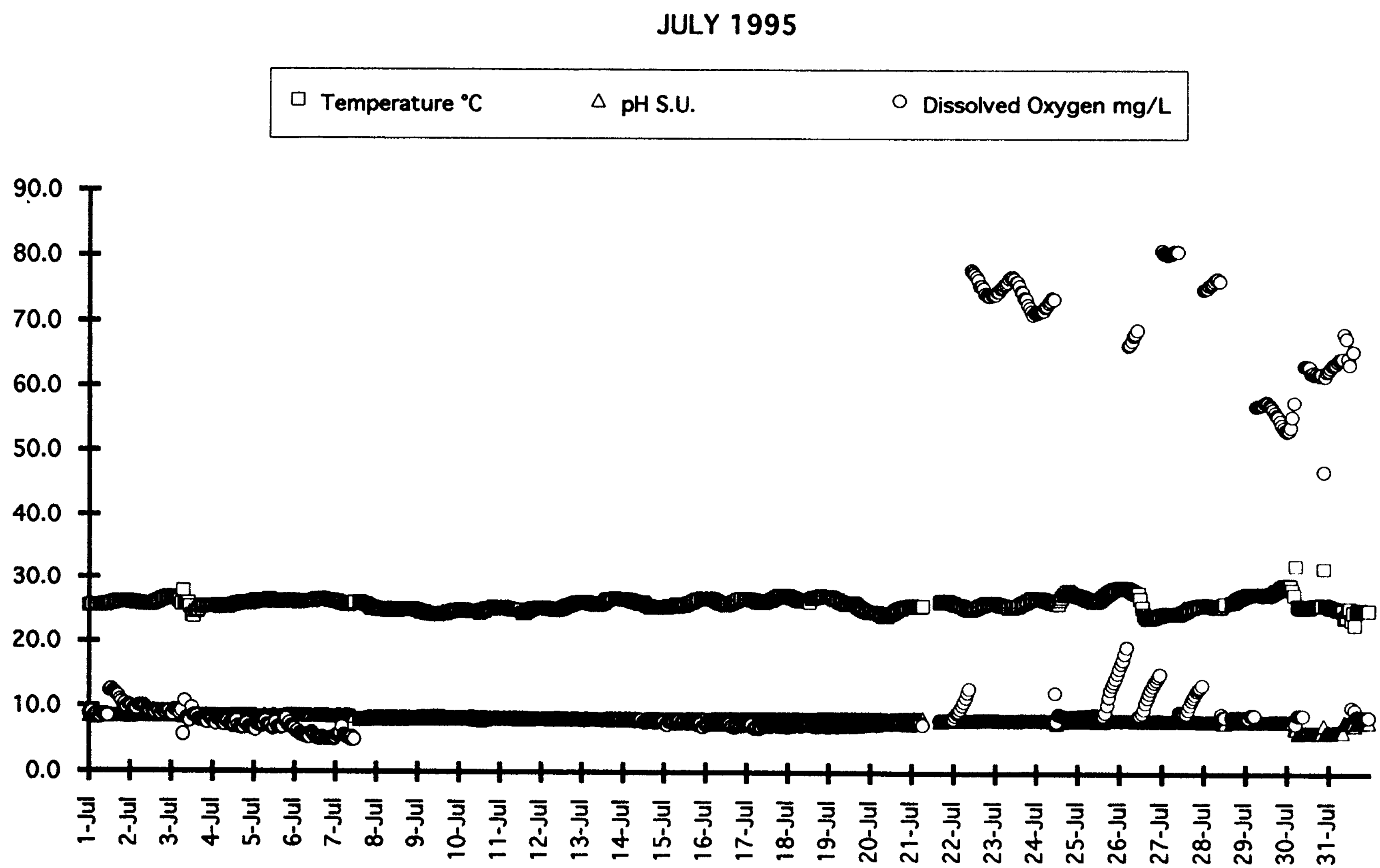

Figure 4-2.3c. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during July 1995.

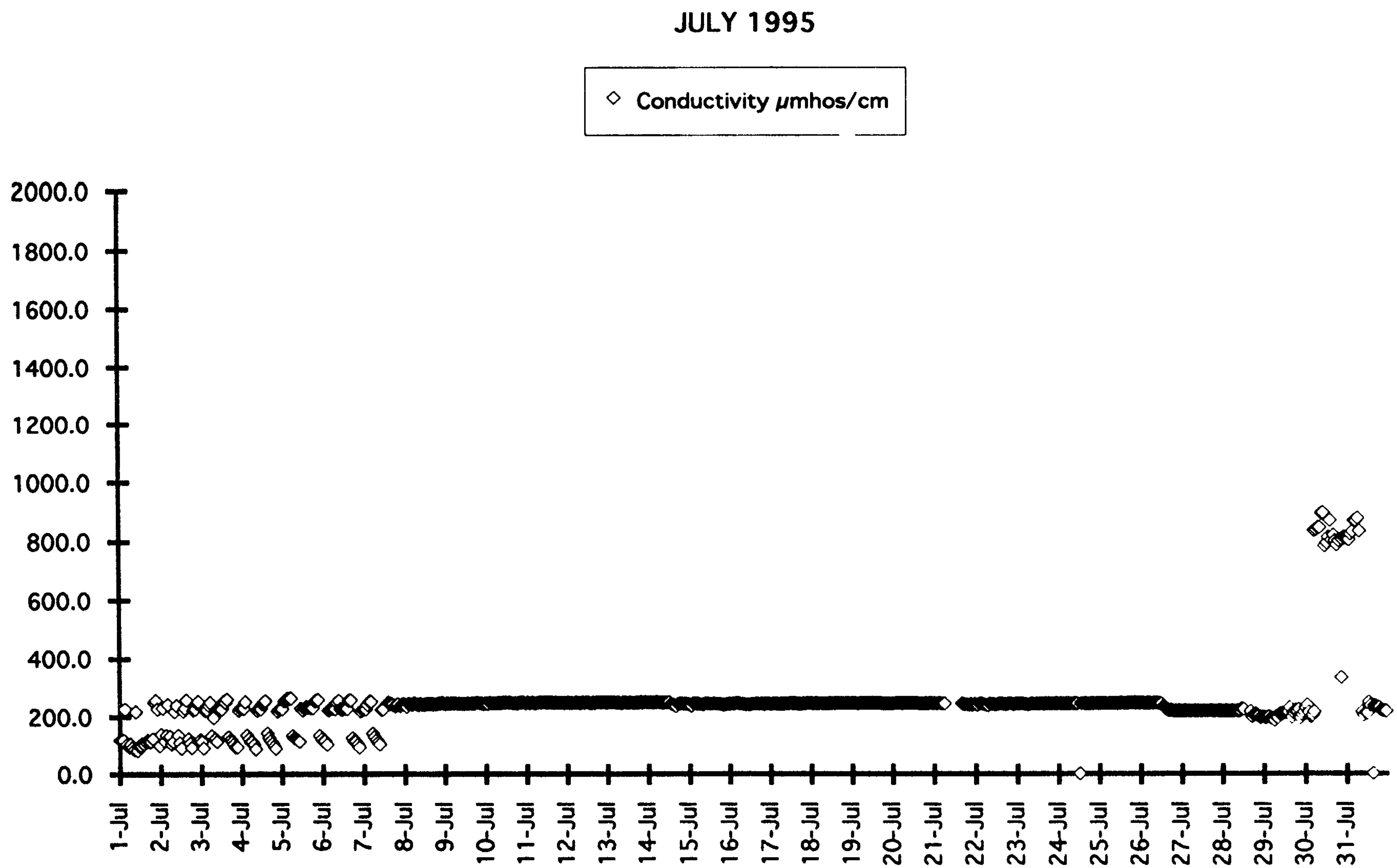

Figure 4-2.3d. Control water conductivity data obtained by the Hydrolab System during July 1995.

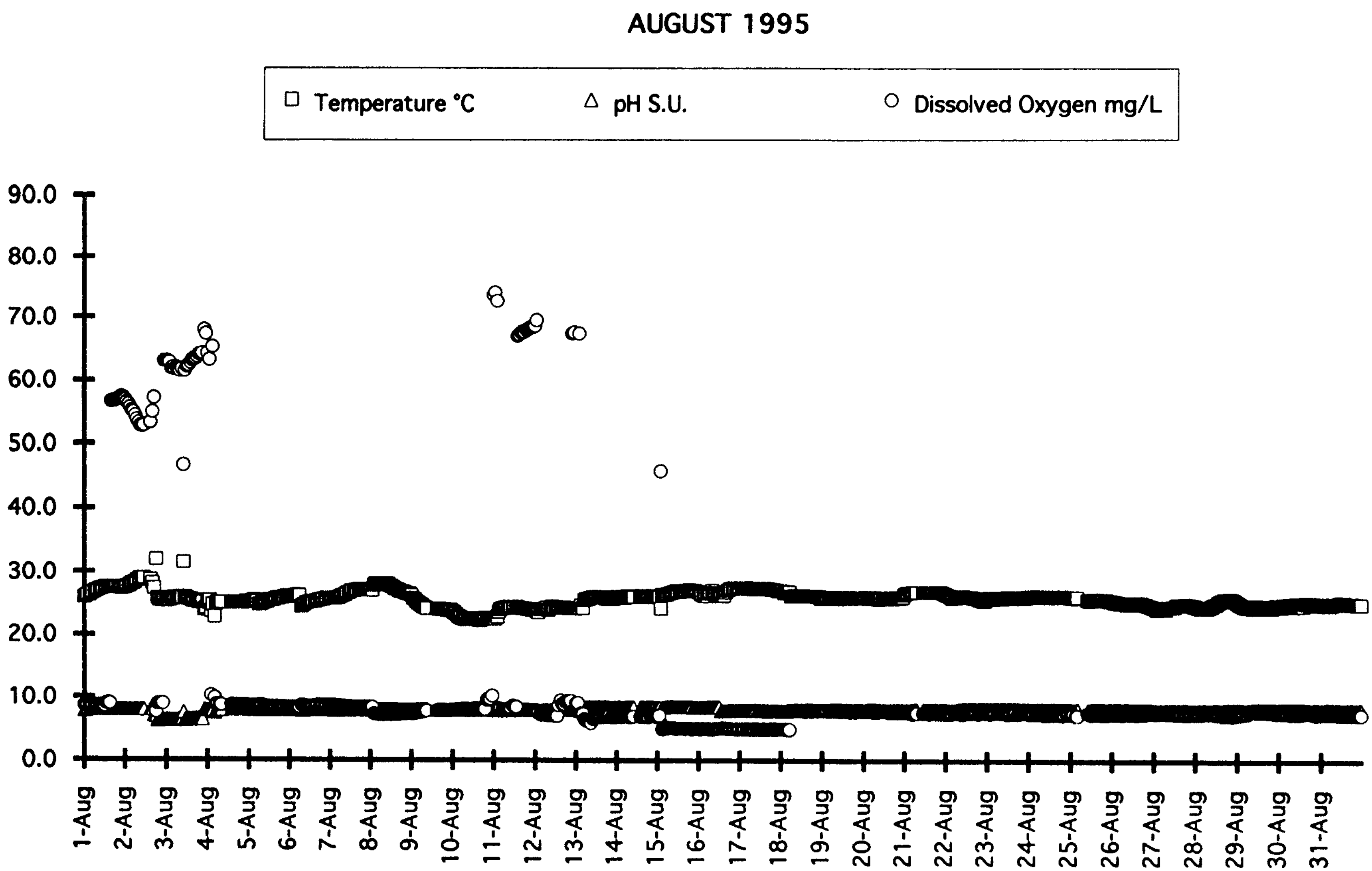

Figure 4-2.3e. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during August 1995.

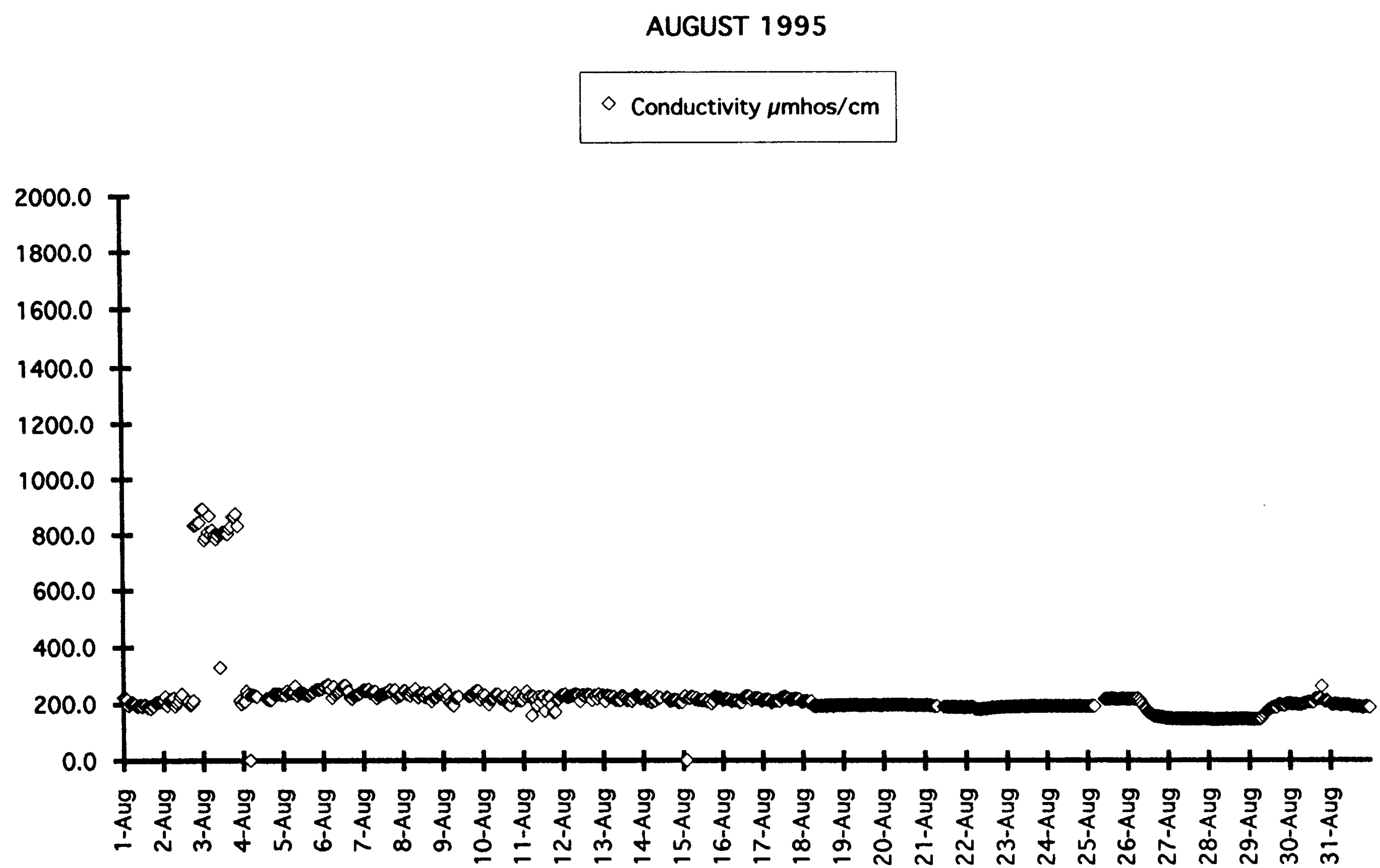

Figure 4-2.3f. Control water conductivity data obtained by the Hydrolab System during August 1995.

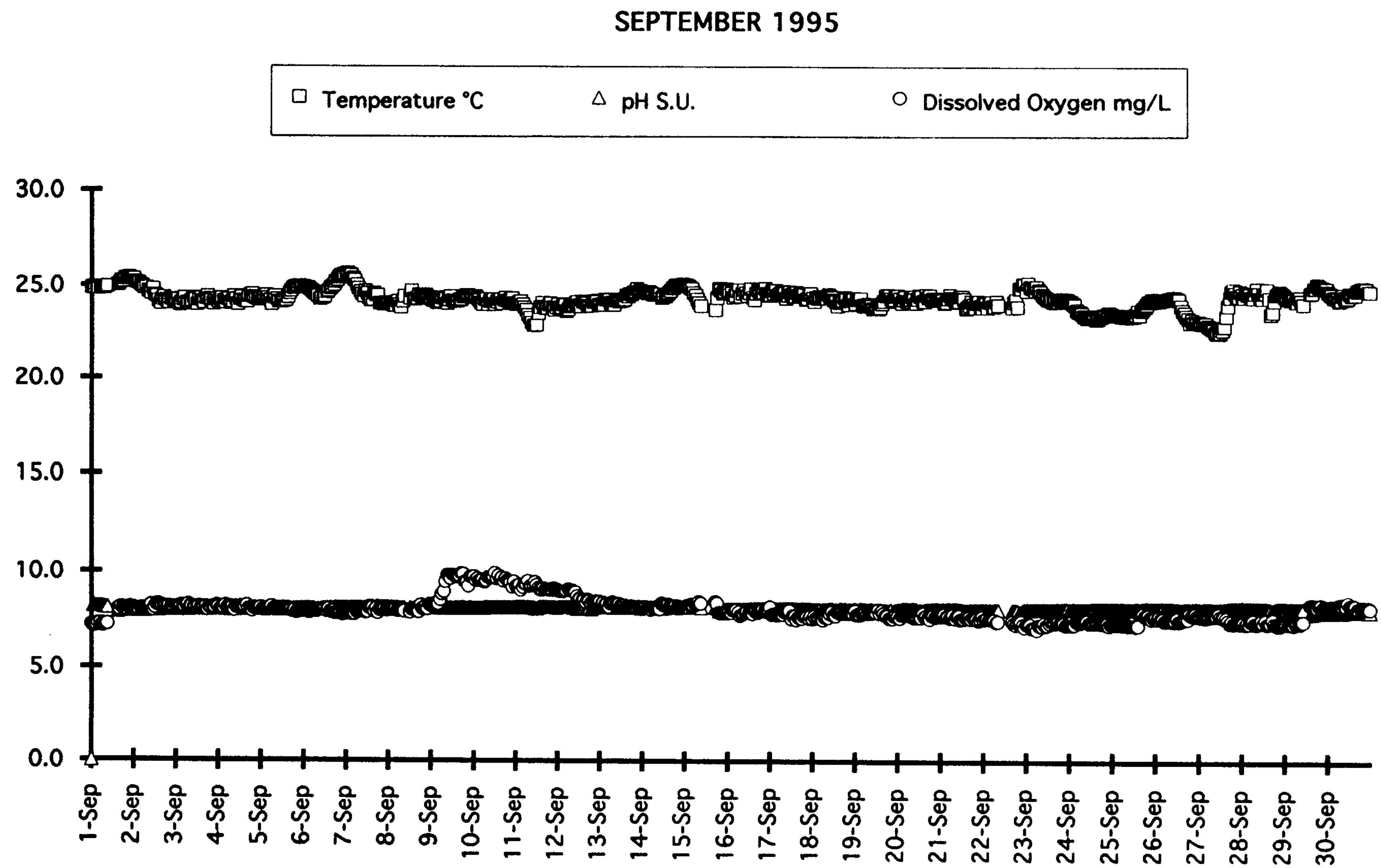

Figure 4-2.3g. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during September 1995.

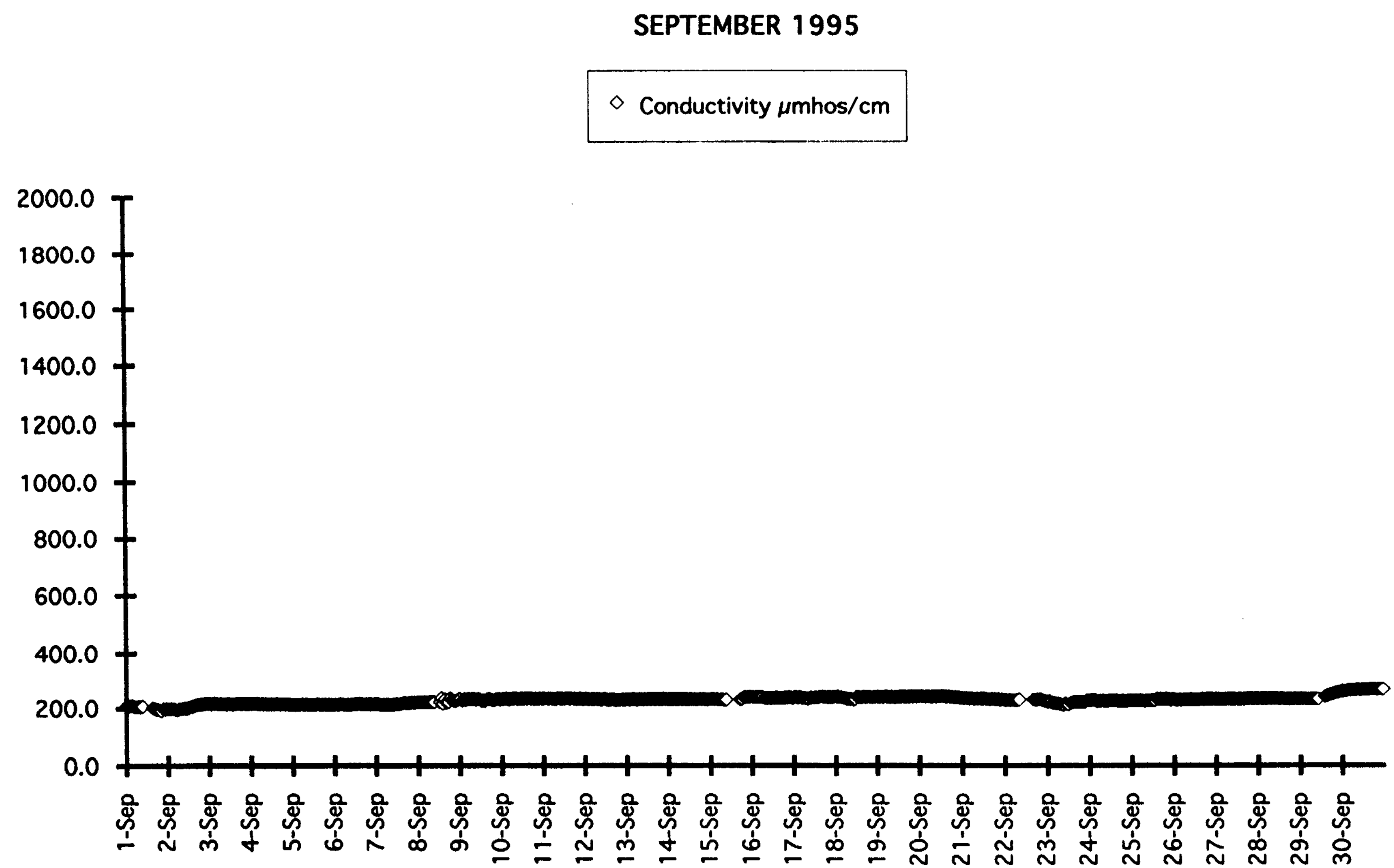

Figure 4-2.3h. Control water conductivity data obtained by the Hydrolab System during Sepember 1995.

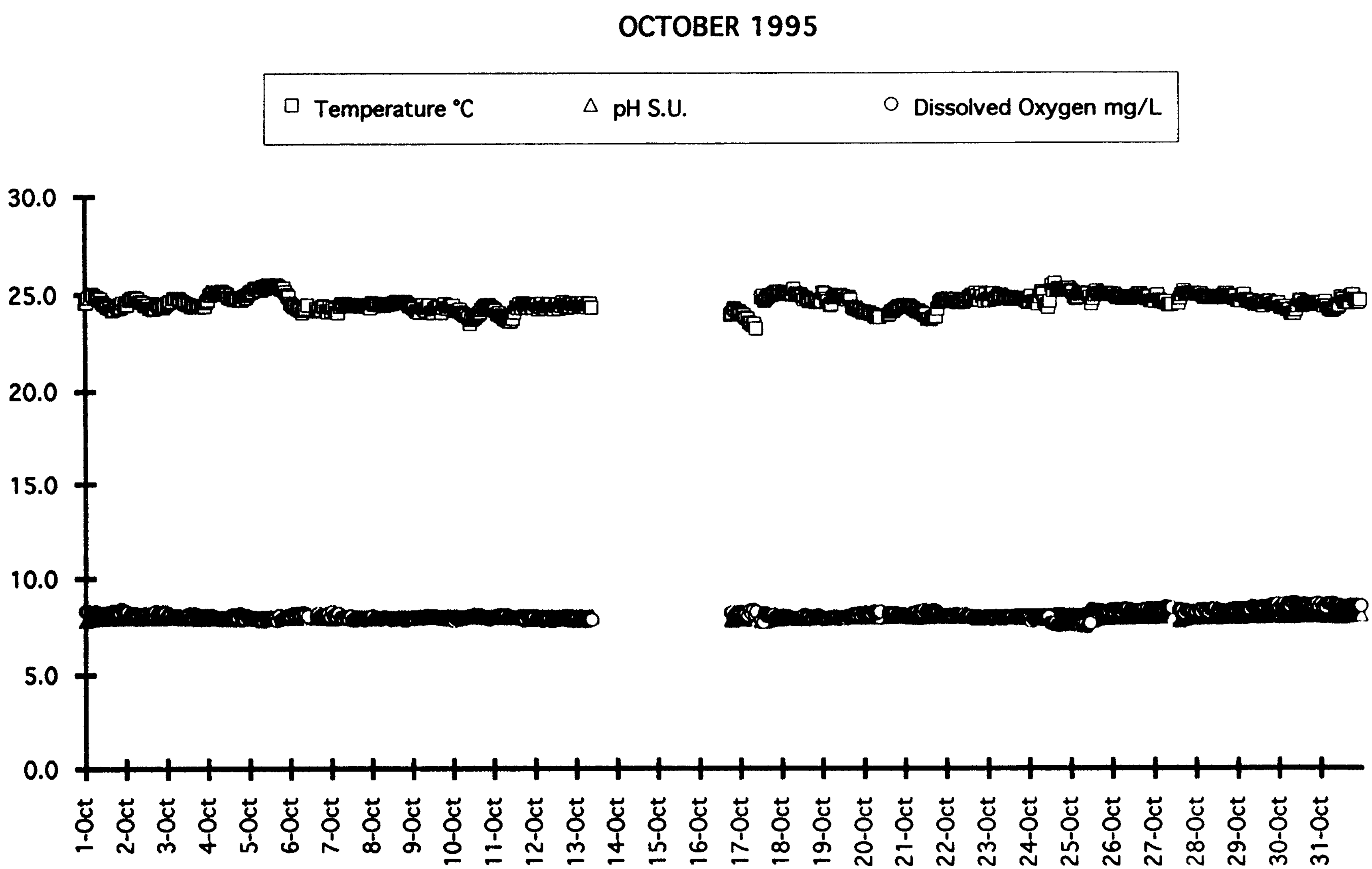

Figure 4-2.3i. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during October 1995.

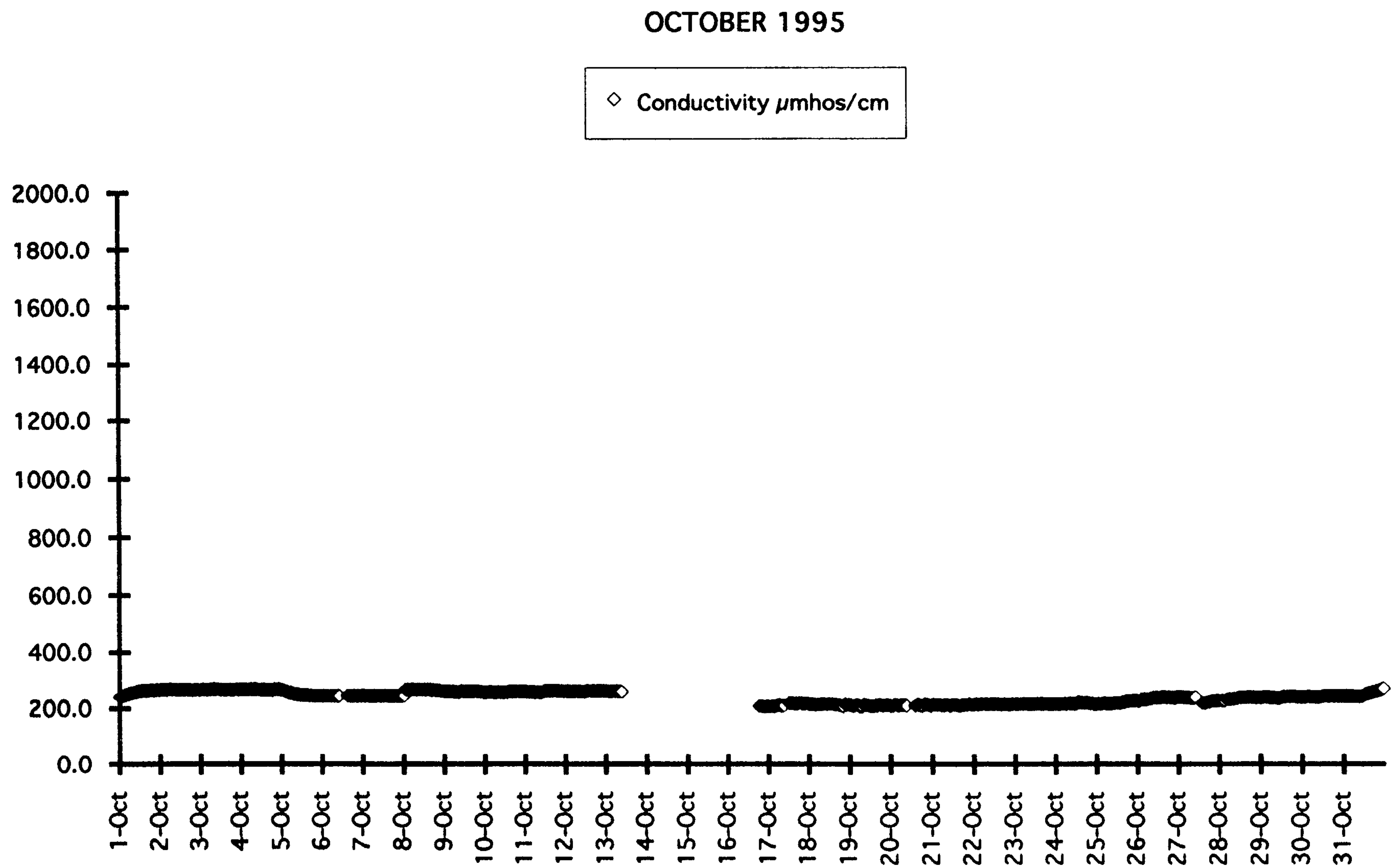

Figure 4-2.3j. Control water conductivity data obtained by the Hydrolab System during October 1995.

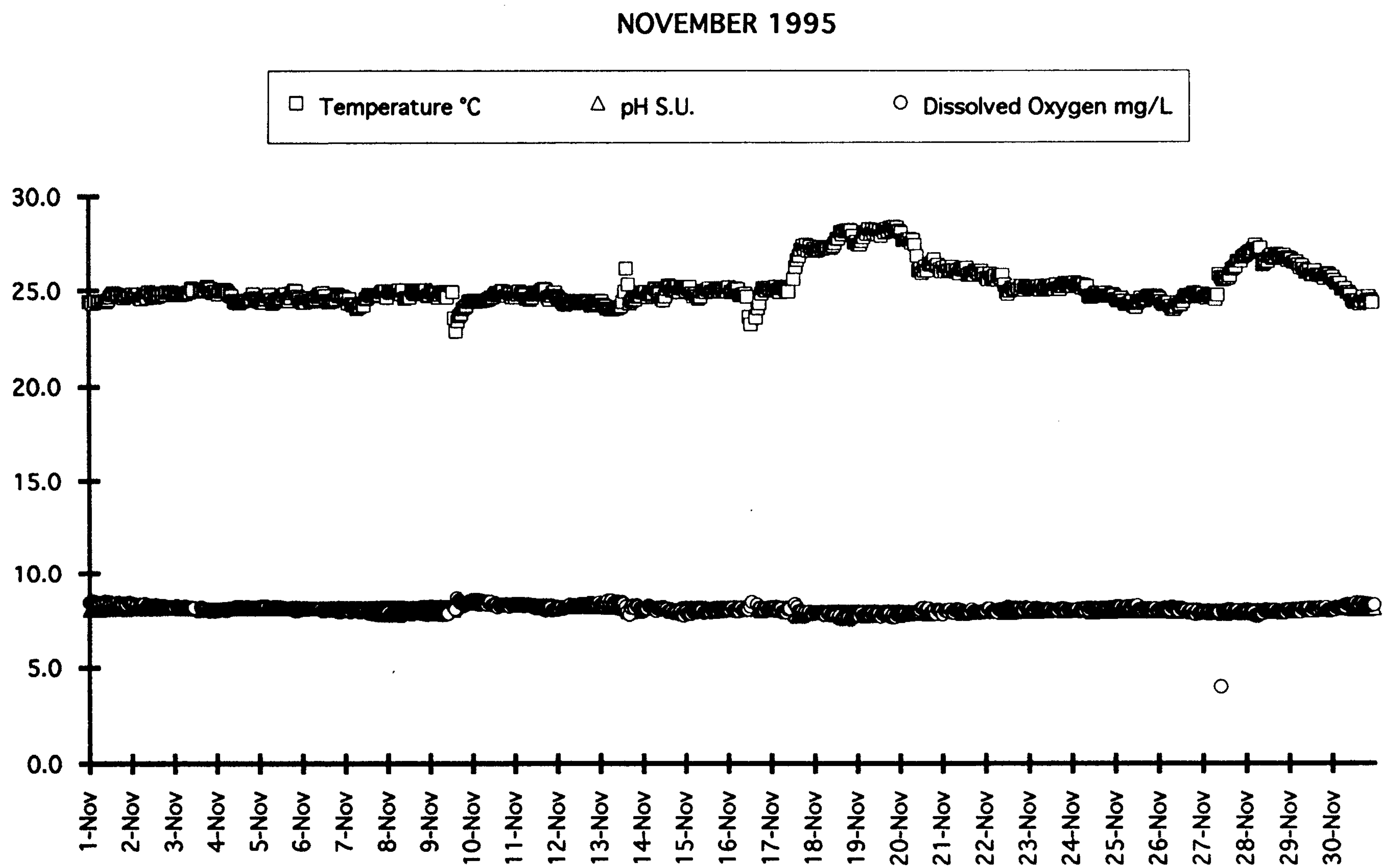

Figure 4-2.3k. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during November 1995.

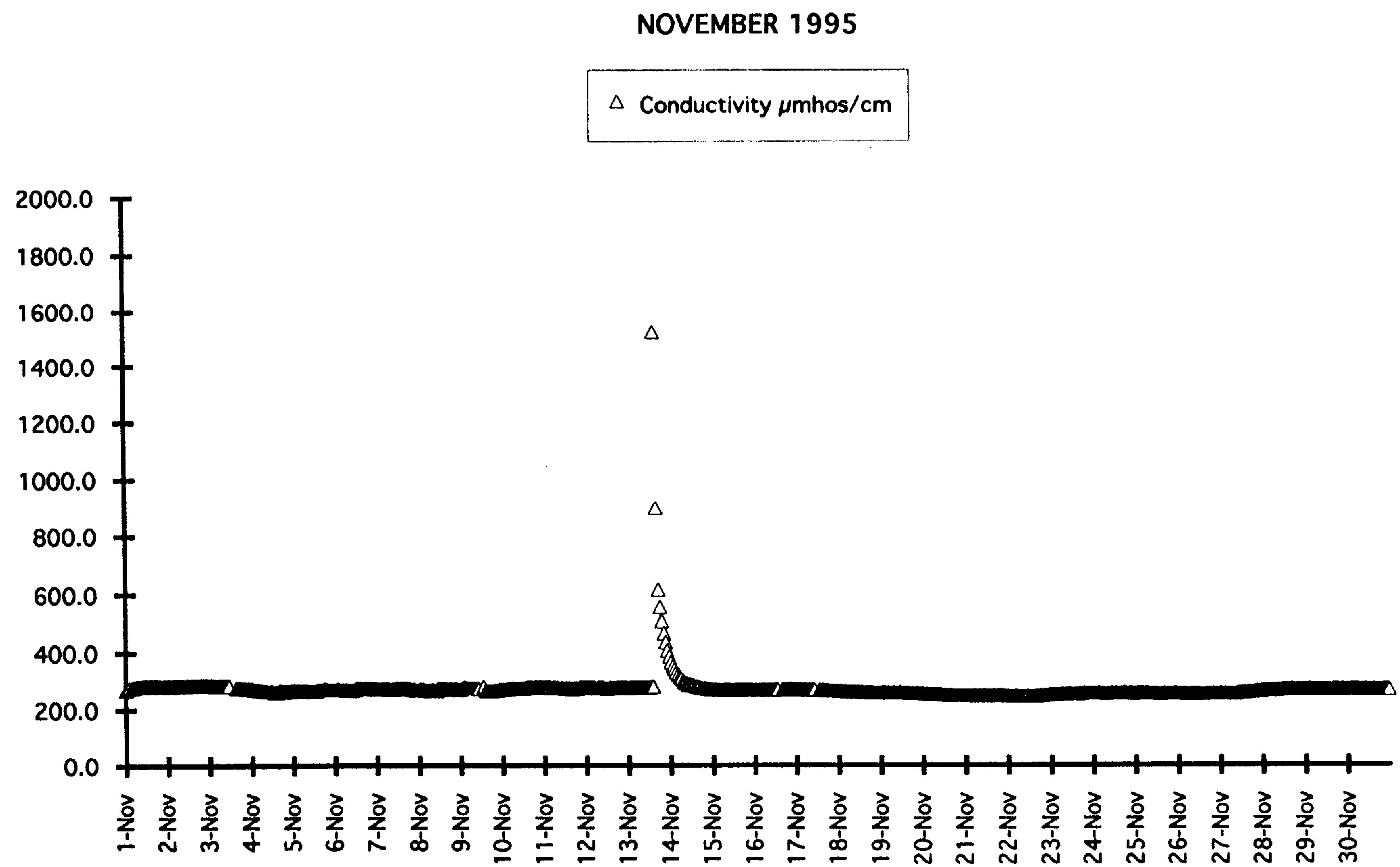

Figure 4-2.3l. Control water conductivity data obtained by the Hydrolab System during November 1995.

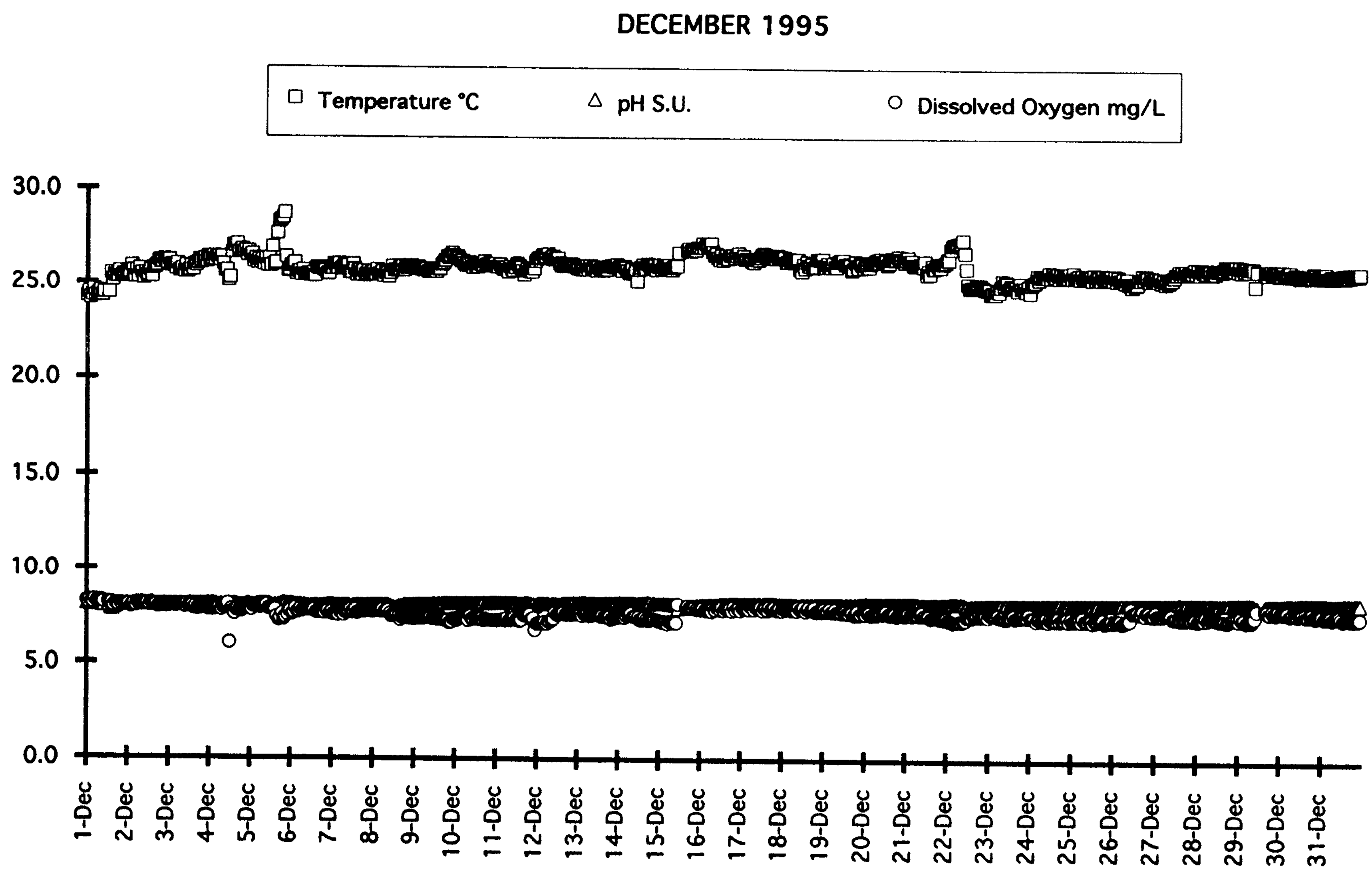

Figure 4-2.3m. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during December 1995.

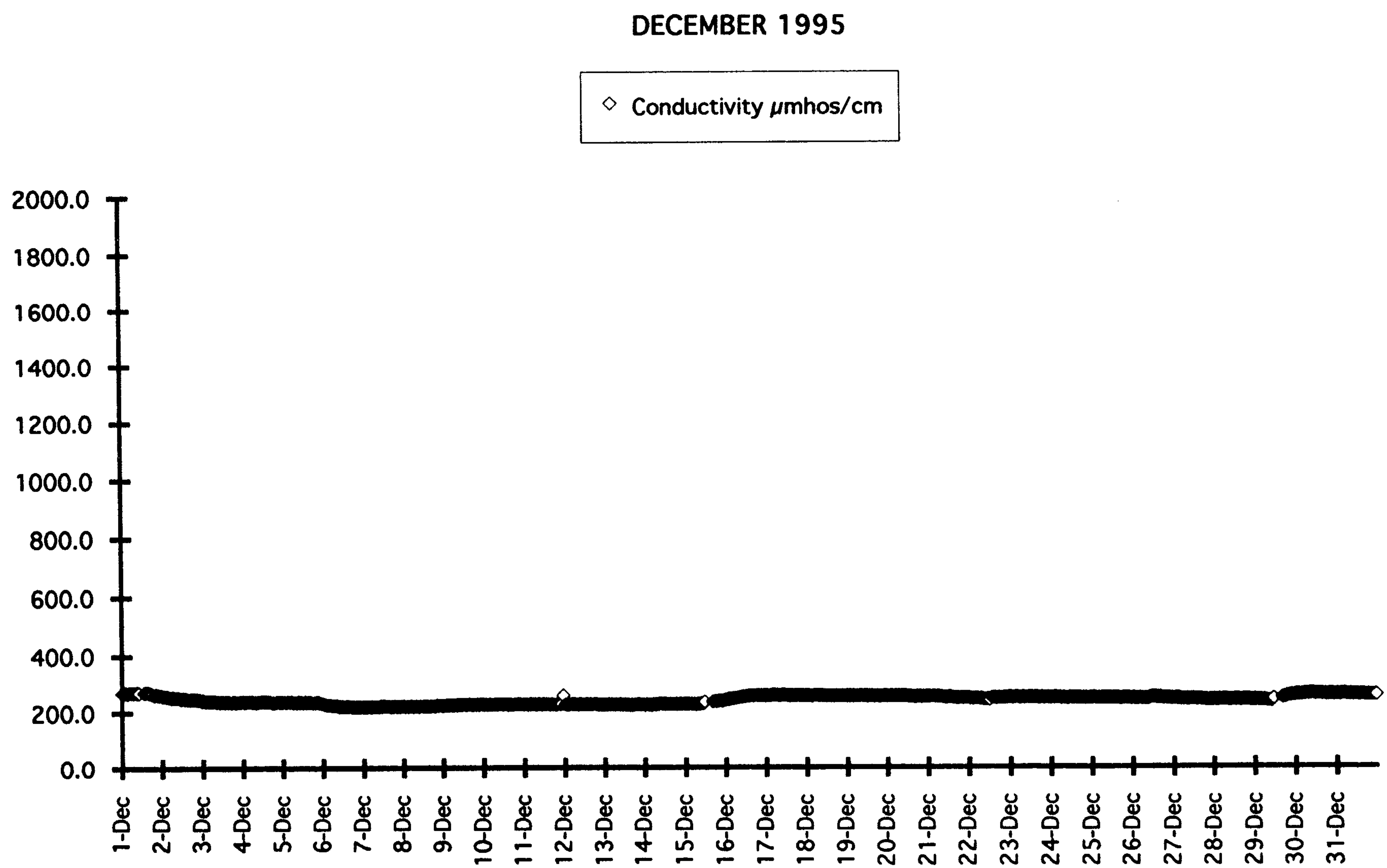

Figure 4-2.3n. Control water conductivity data obtained by the Hydrolab System during December 1995.

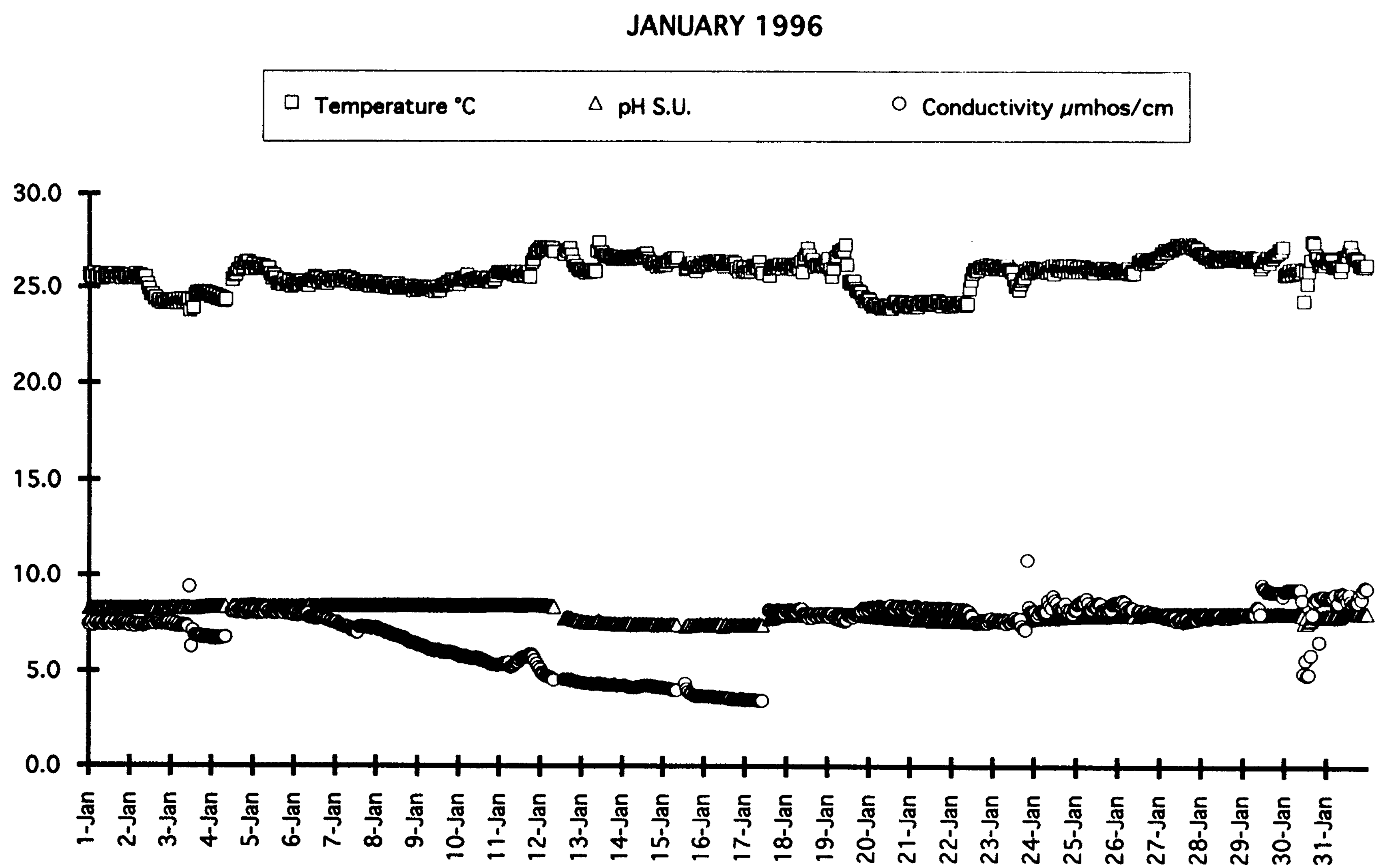

Figure 4-2.3o. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during January 1996.

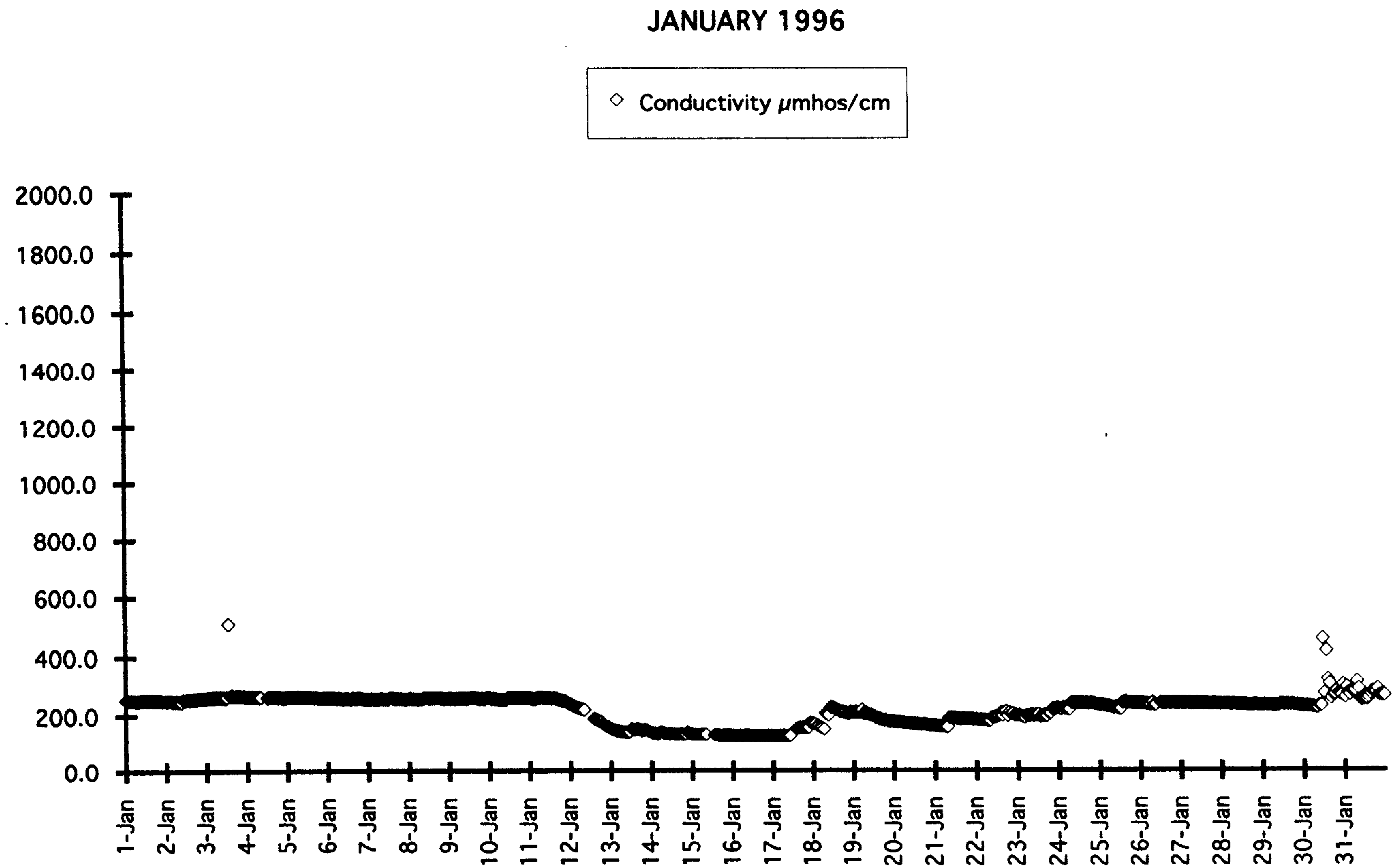

Figure 4-2.3p. Control water conductivity data obtained by the Hydrolab System during January 1996.

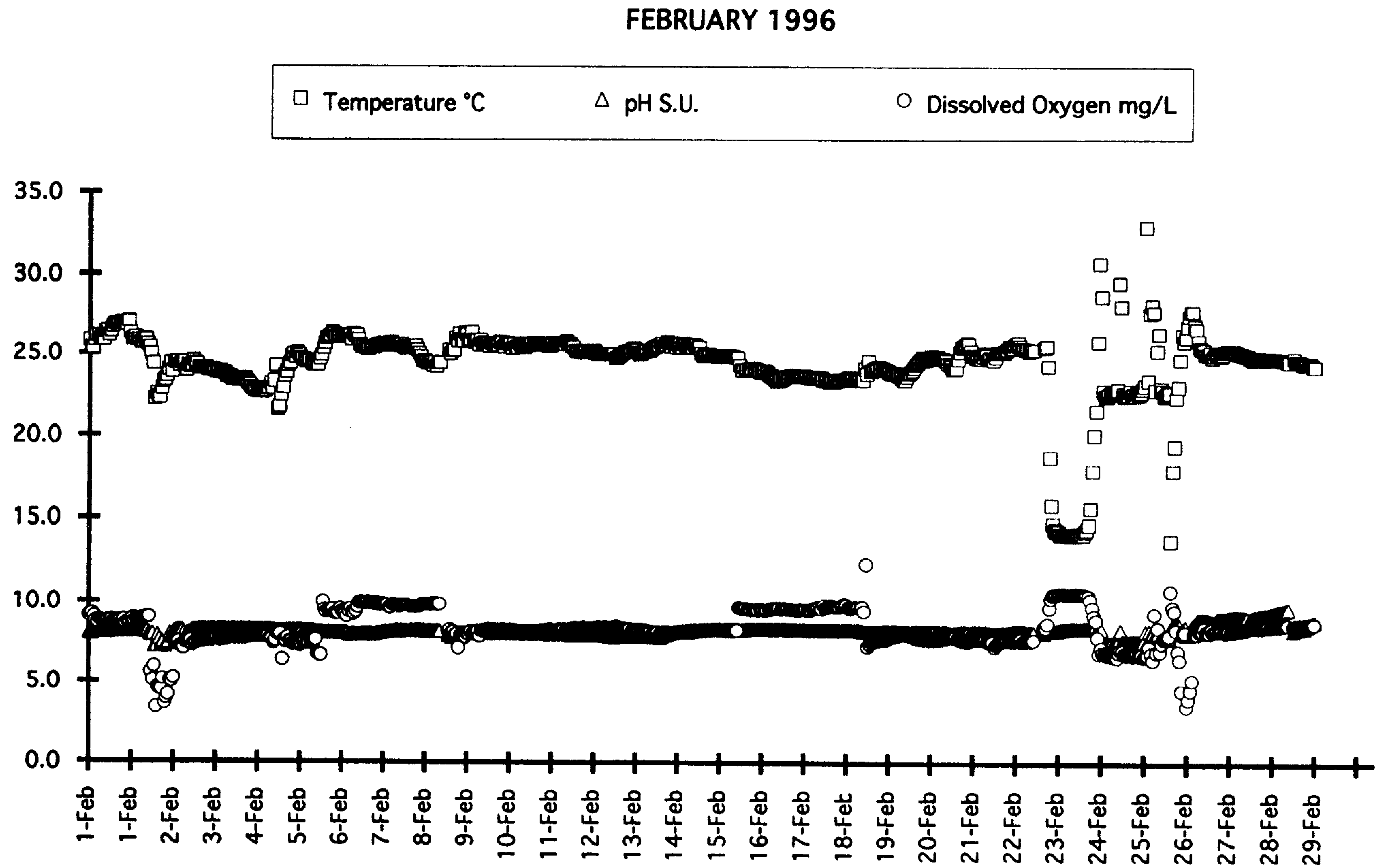

Figure4-2.3q. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during February 1996.

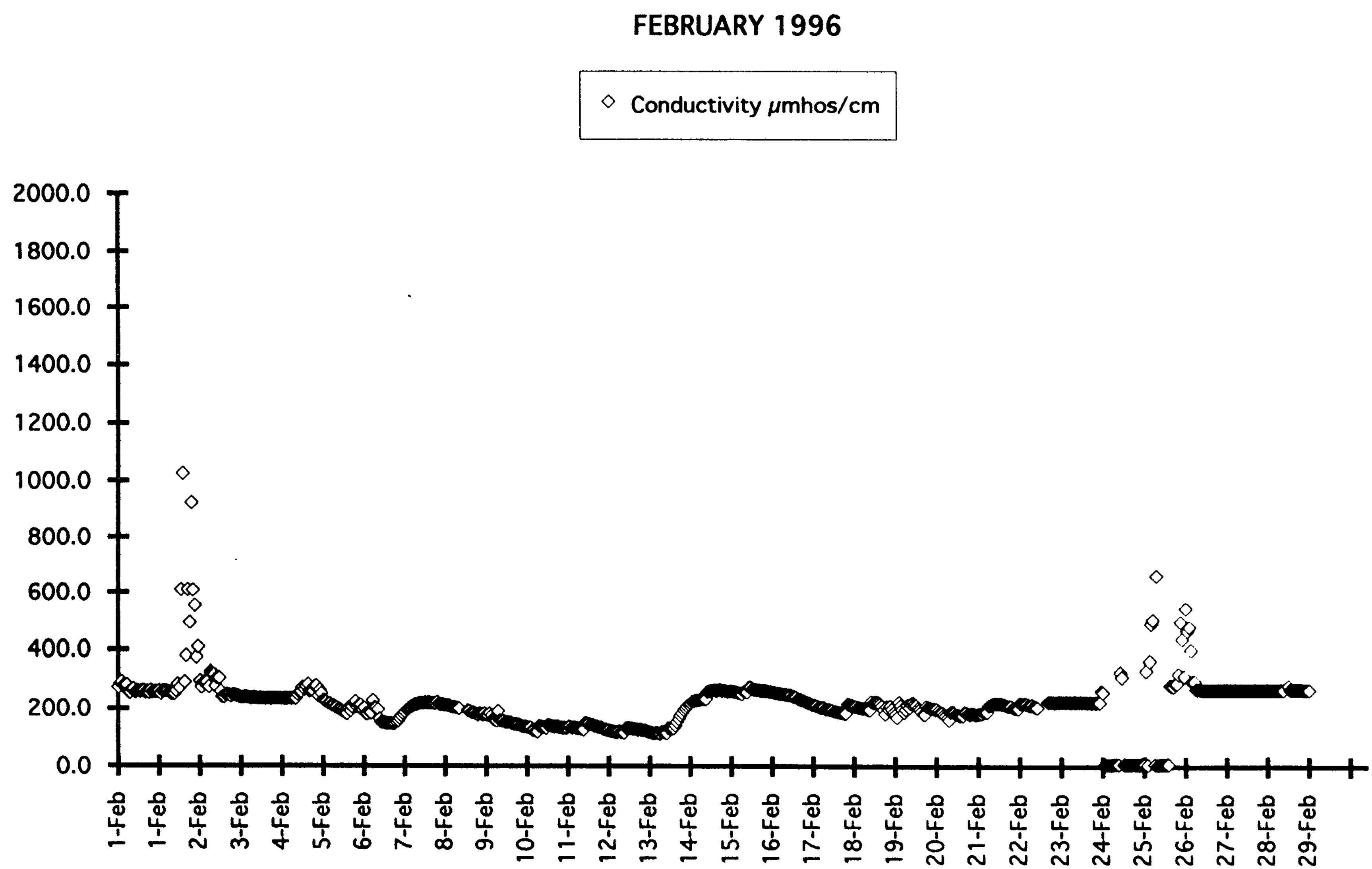

Figure 4-2.3r. Control water conductivity data obtained by the Hydrolab System during February 1996.

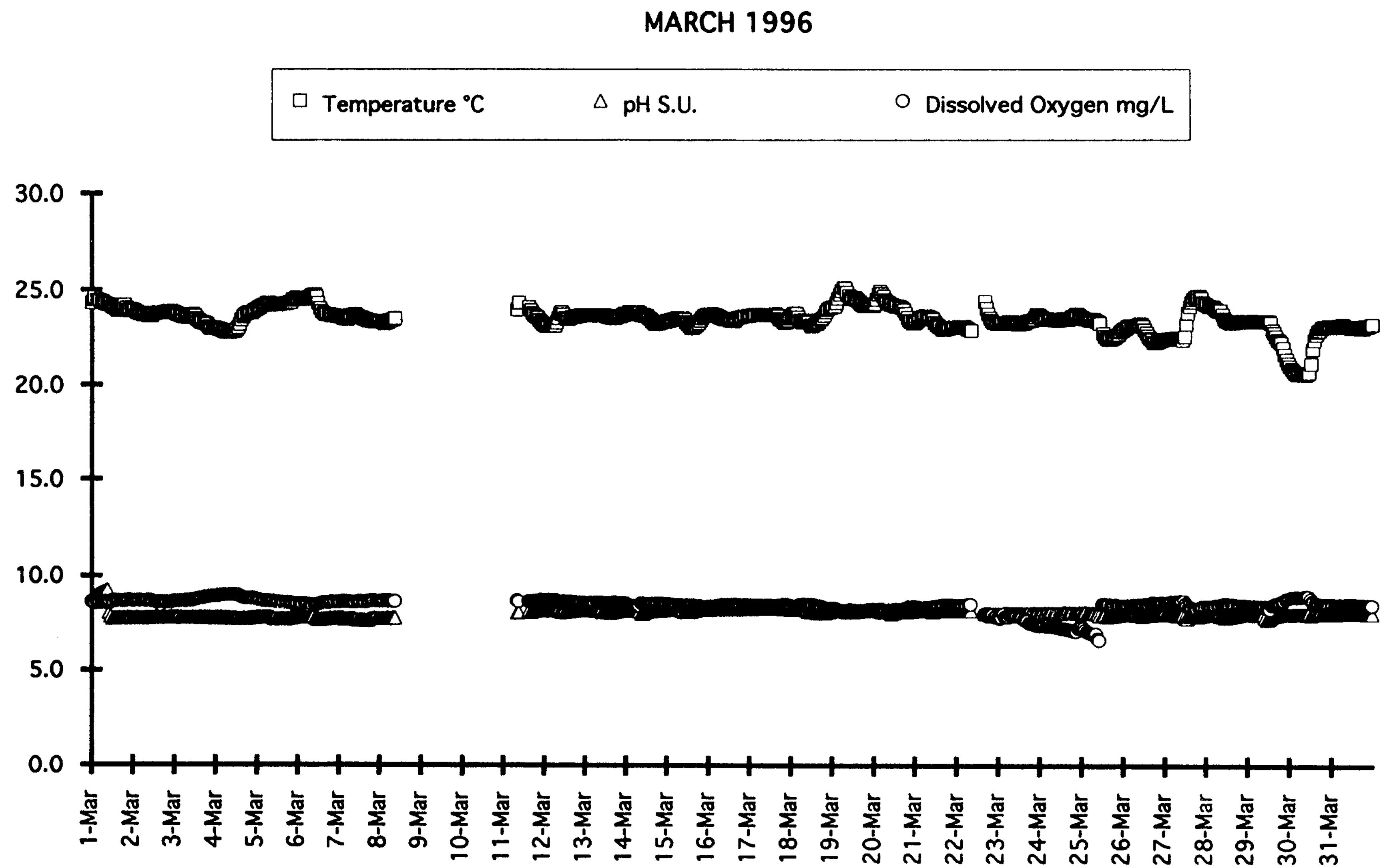

Figure 4-2.3s. Control water temperature, pH, and dissolved oxygen data obtained by the Hydrolab System during March 1996.

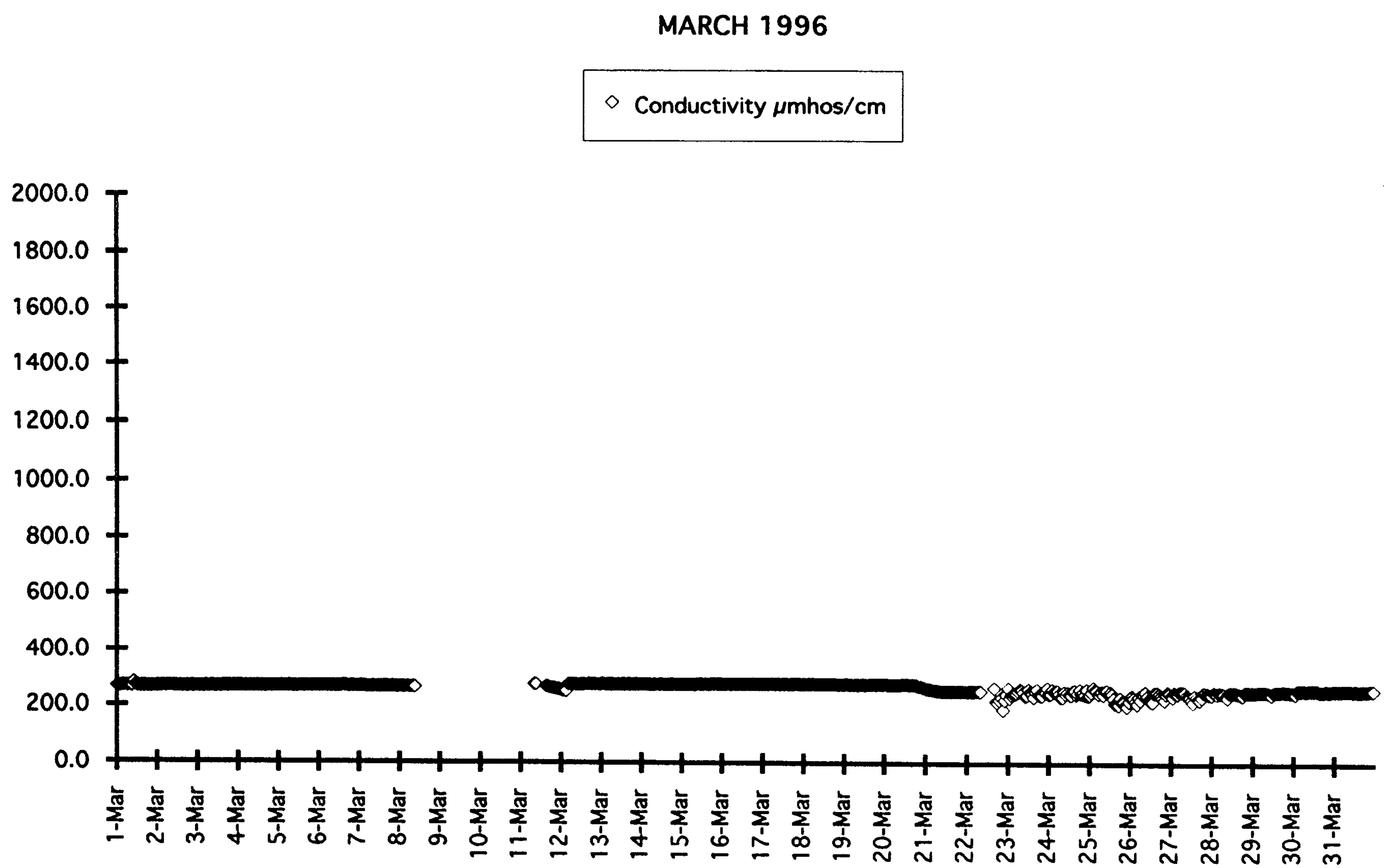

Figure 4-2.3t. Control water conductivity data obtained by the Hydrolab System during March 1996.

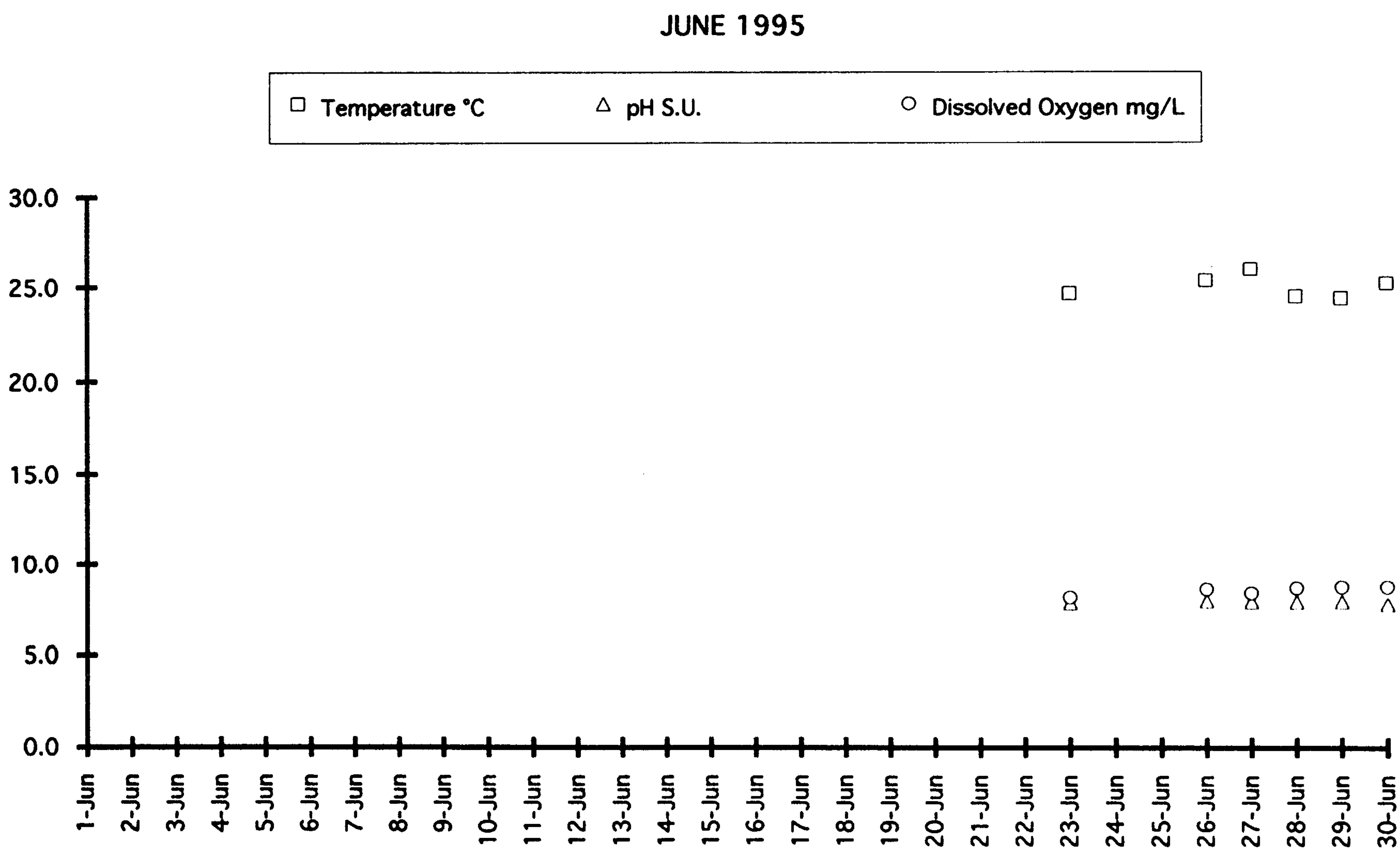

Figure 4-2.4a. Control water temperature, pH, and dissolved oxygen data obtained manually during June 1995.

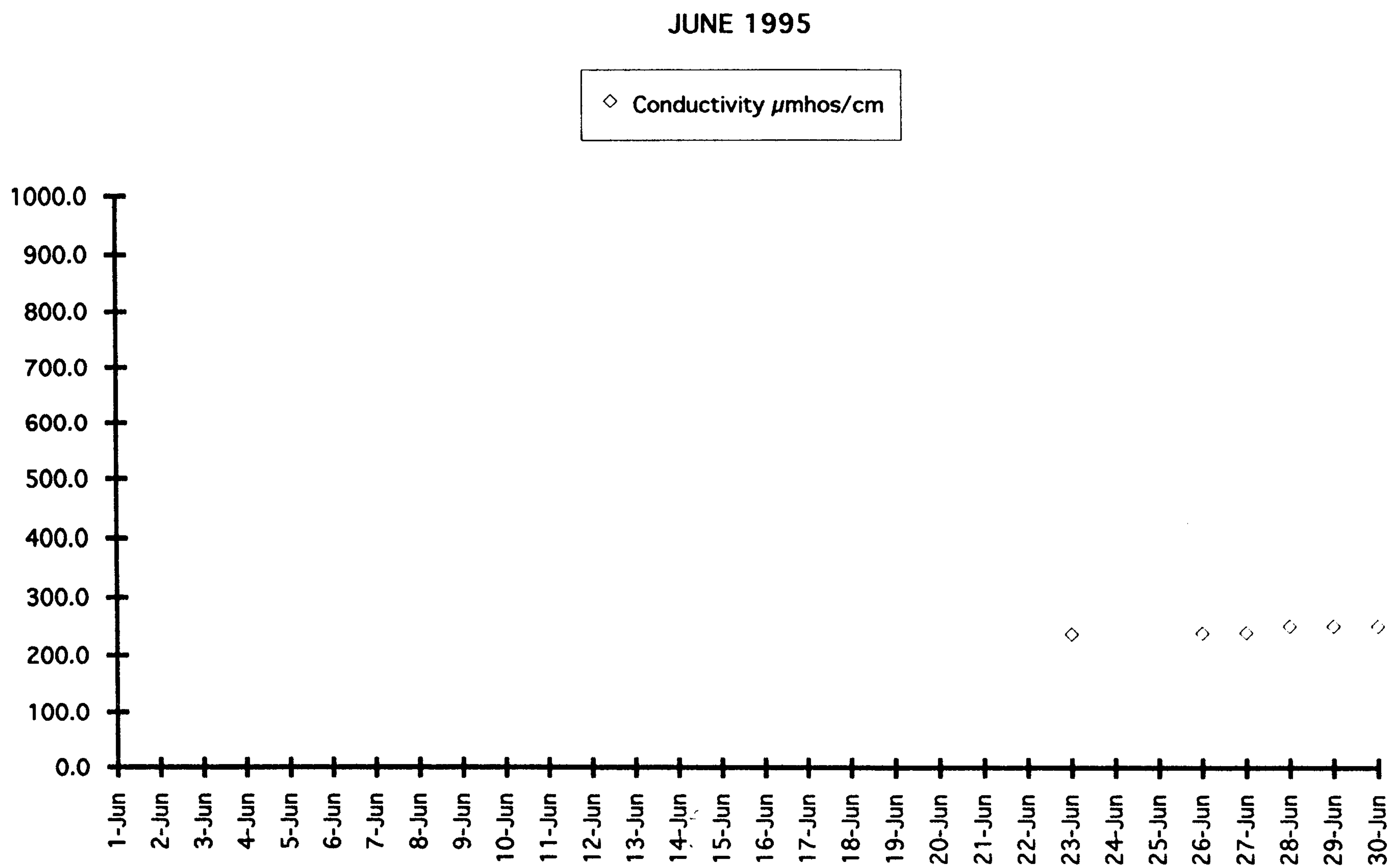

Figure 4-2.4b. Control water conductivity obtained manually during June 1995.

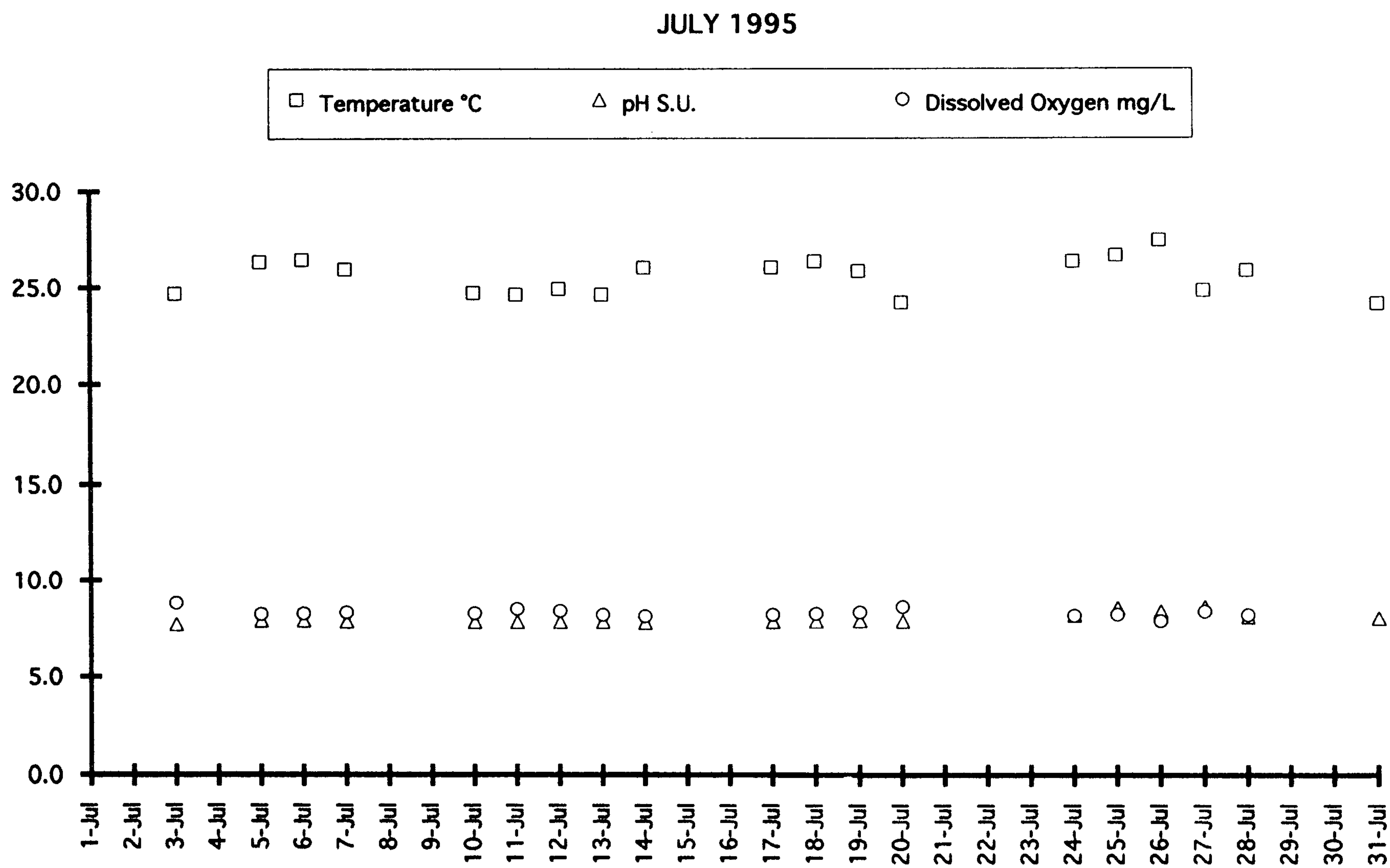

Figure 4-2.4c. Control water temperature, pH, and dissolved oxygen data obtained manually during July 1995.

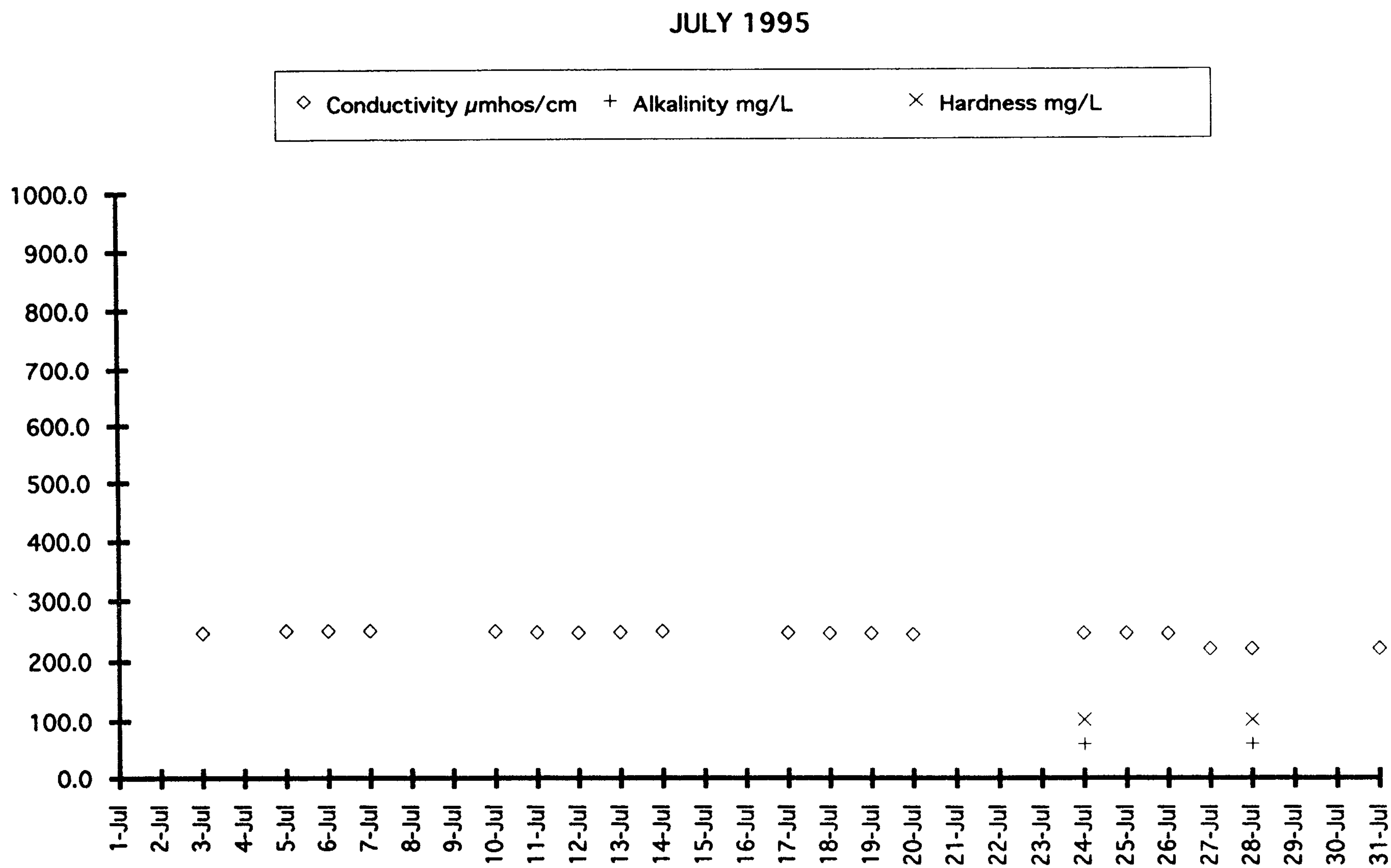

Figure 4-2.4d. Control water conductivity, alkalinity, and hardness data obtained manually during July 1995.

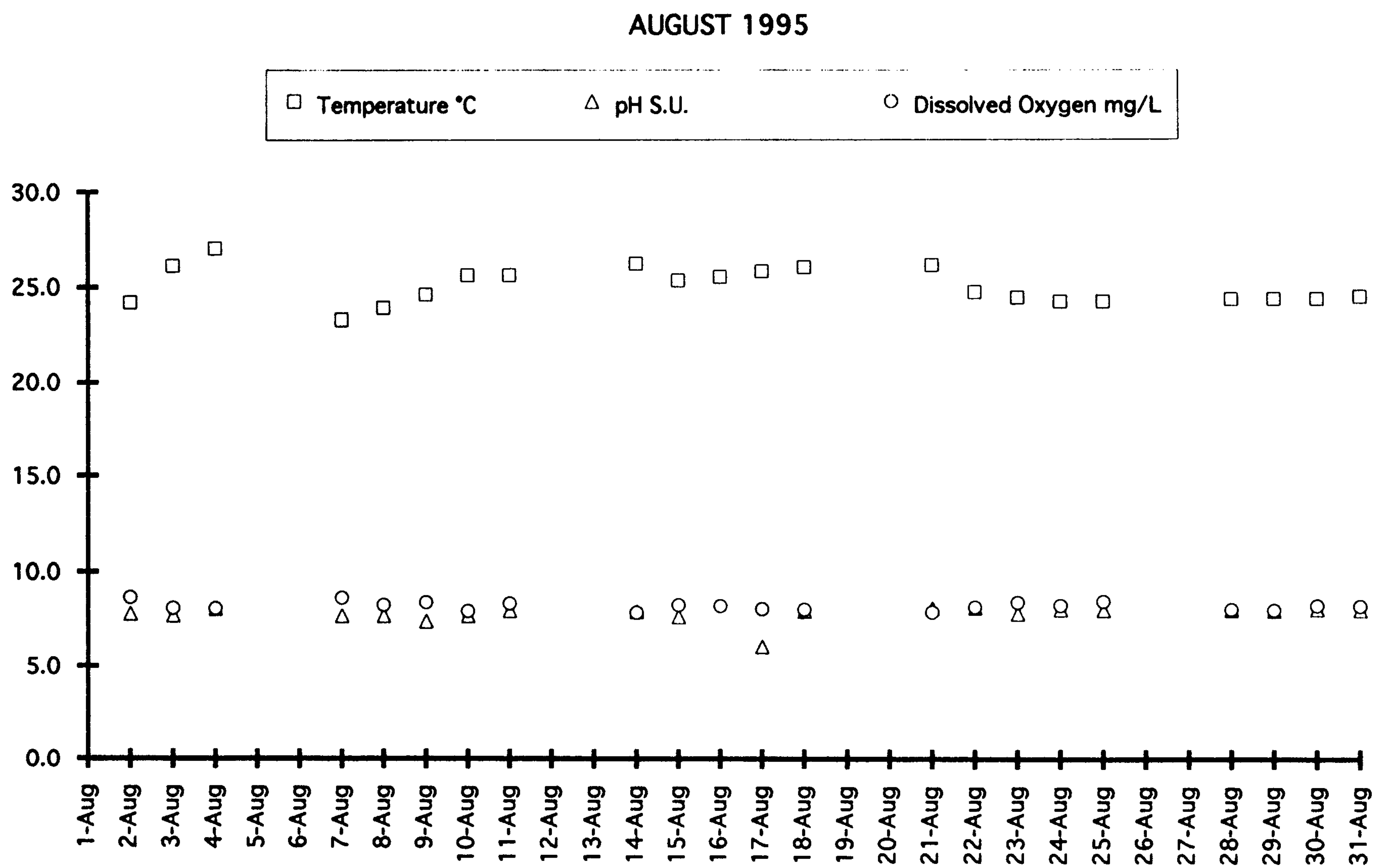

Figure 4-2.4e. Control water temperature, pH, and dissolved oxygen data obtained manually during August 1995.

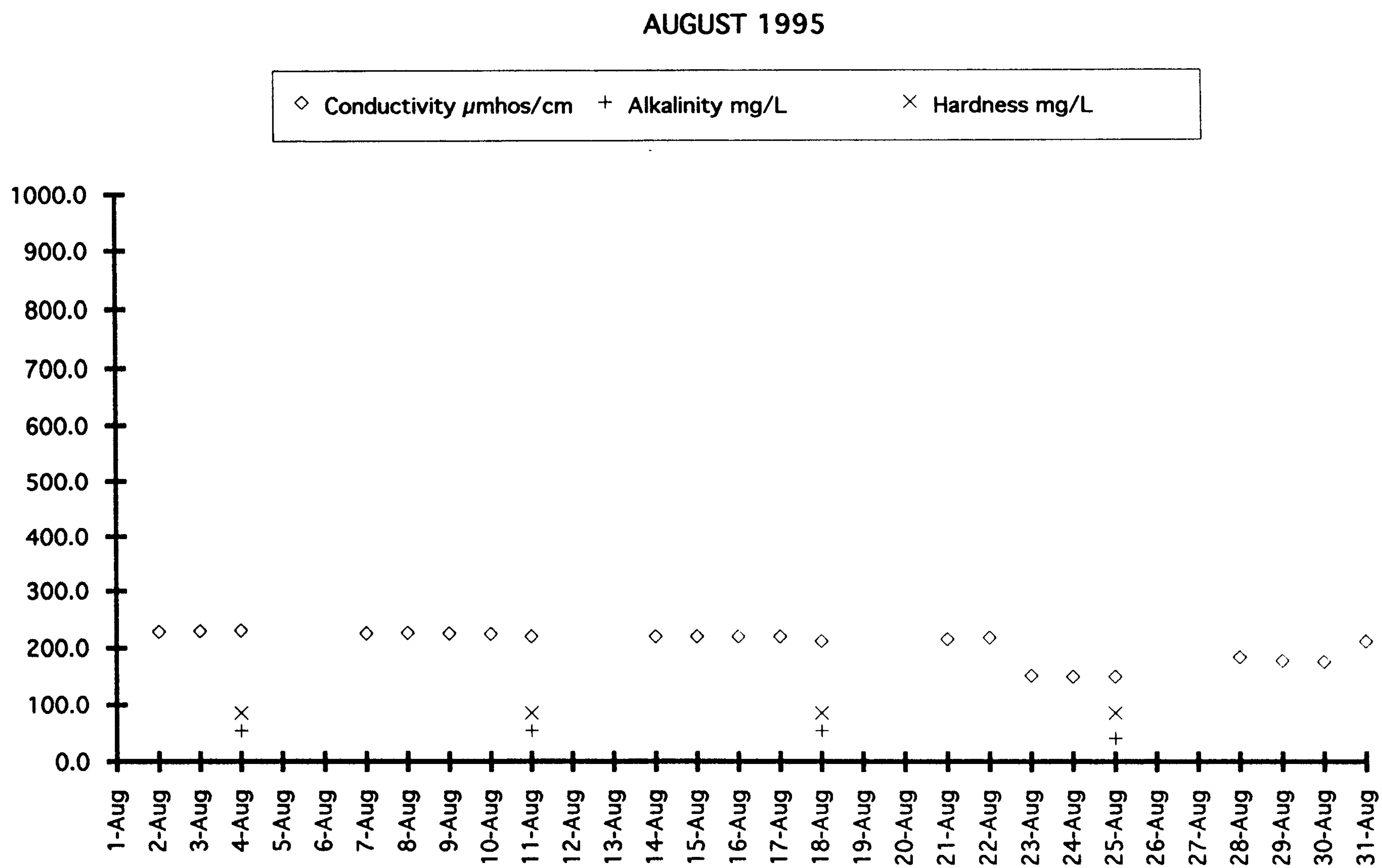

Figure 4-2.4f. Control water conductivity, alkalinity, and hardness data obtained manually during August 1995.

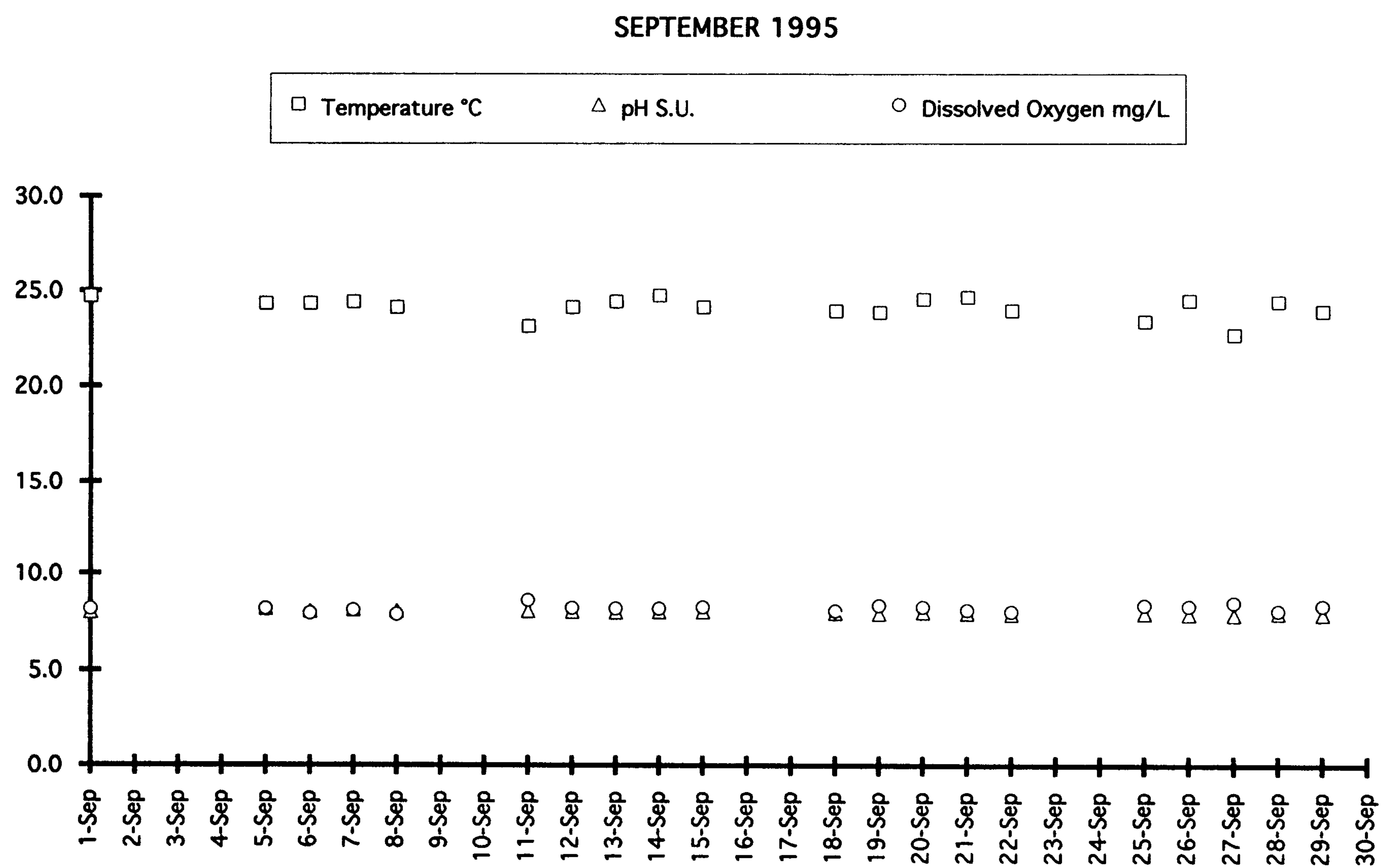

Figure 4-2.4g. Control water temperature, pH, and dissolved oxygen data obtained manually during September 1995.

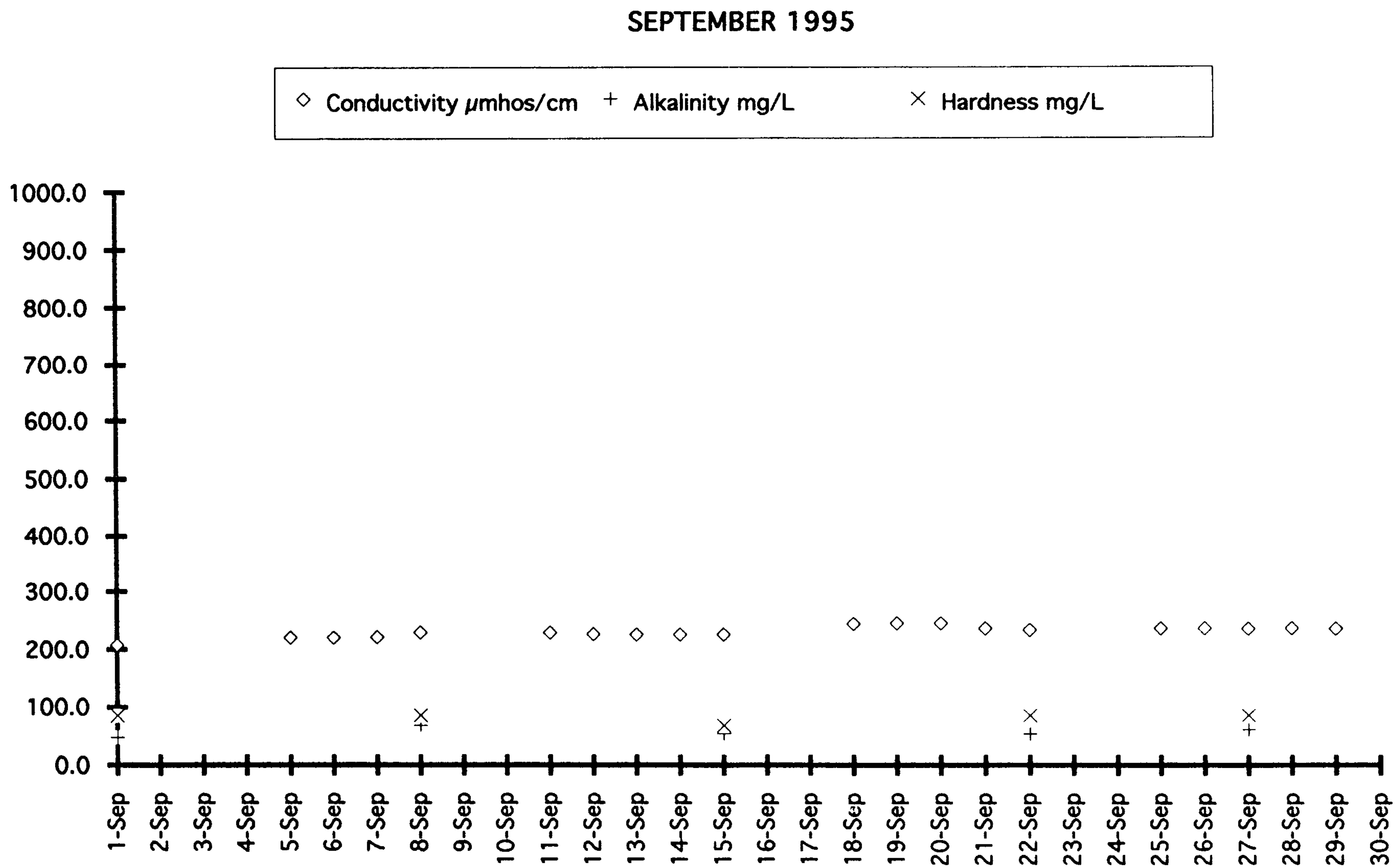

Figure 4-2.4h. Control water conductivity, alkalinity, and hardness data obtained manually during September 1995.

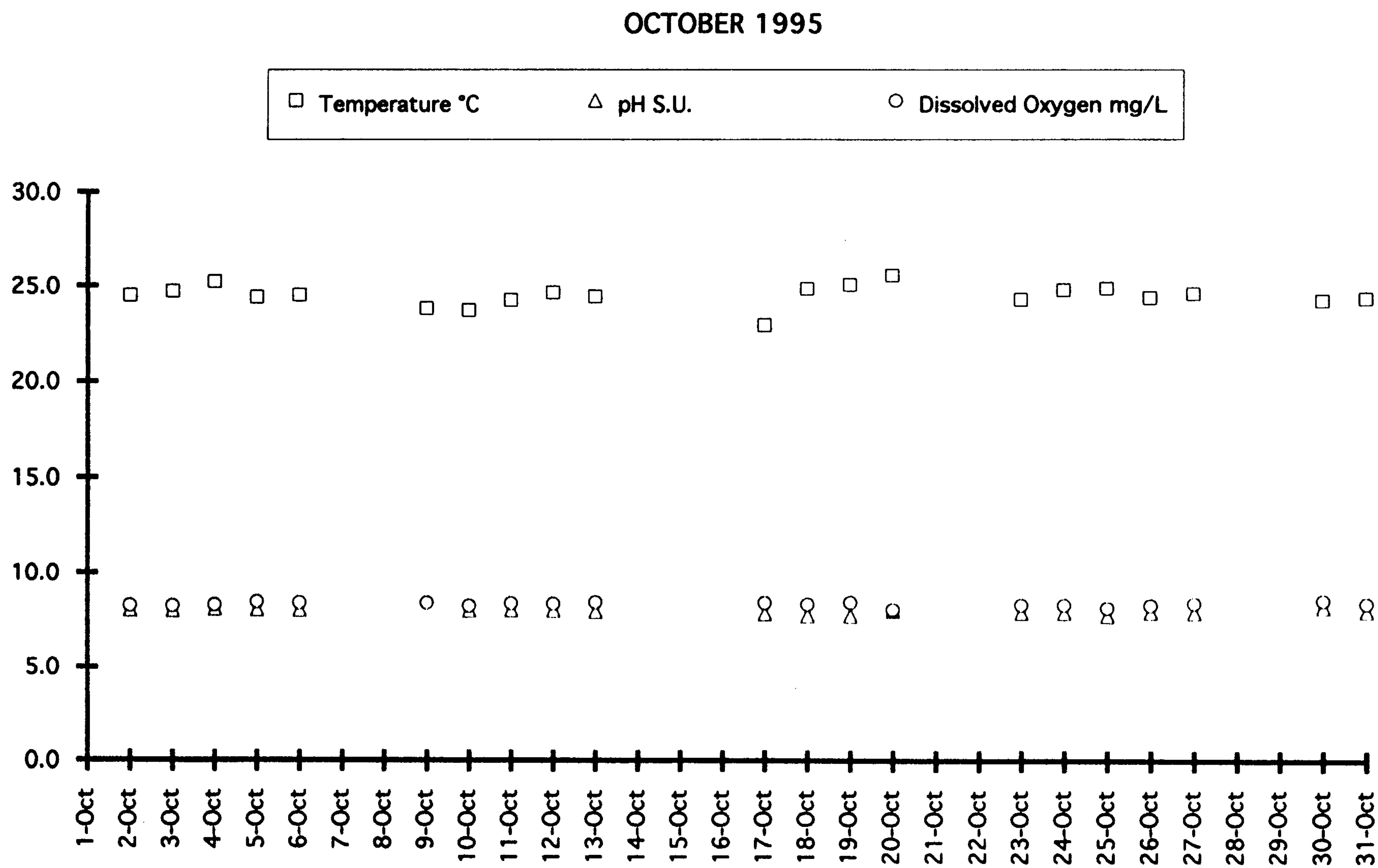

Figure 4-2.4i. Control water temperature, pH, and dissolved oxygen data obtained manually during October 1995.

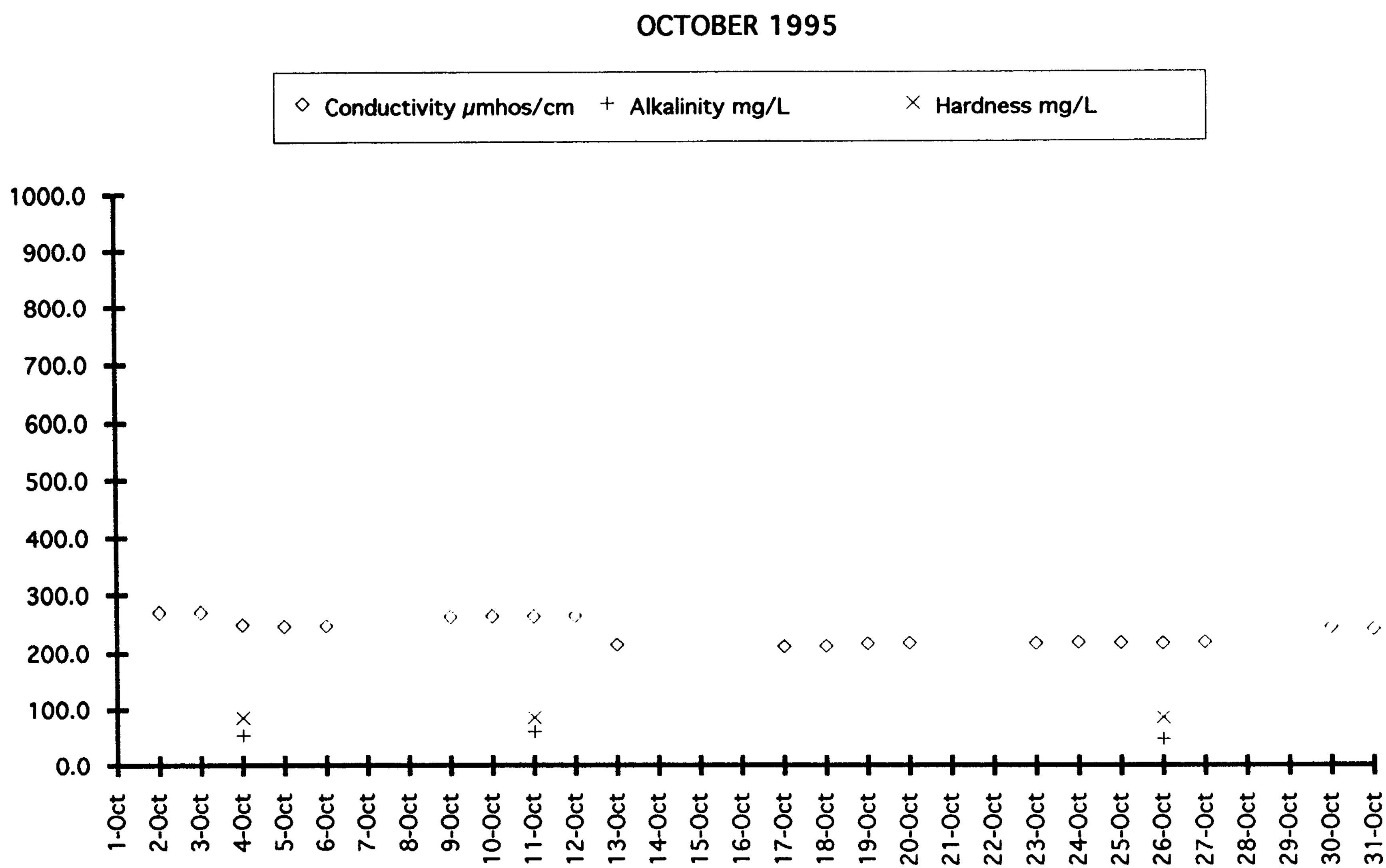

Figure 4-2.4j. Control water conductivity, alkalinity, and hardness data obtained manually during October 1995.

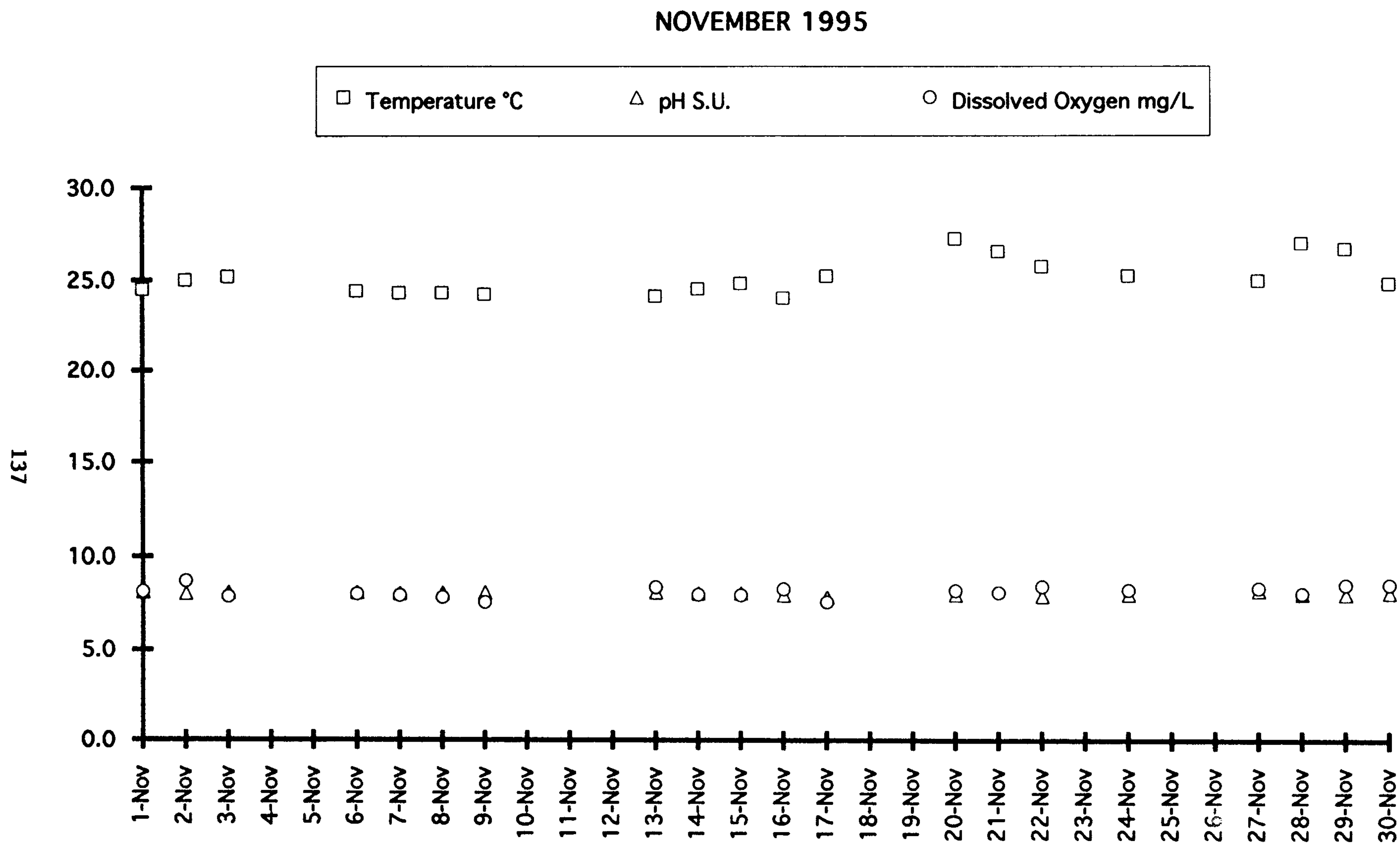

Figure 4-2.4k. Control water temperature, pH, and dissolved oxygen data obtained manually during November 1995.

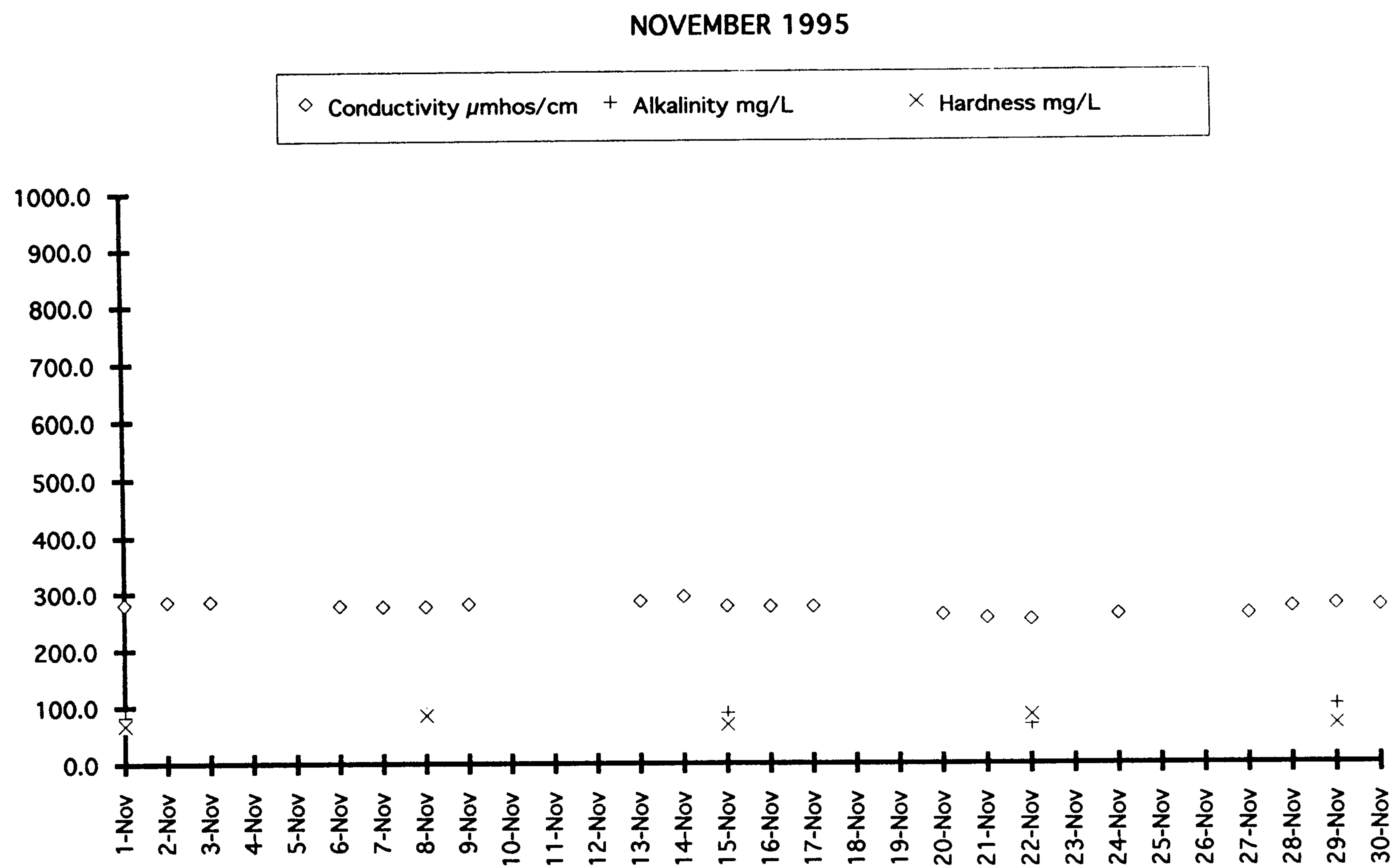

Figure 4-2.4l. Control water conductivity, alkalinity, and hardness data obtained manually during November 1995.

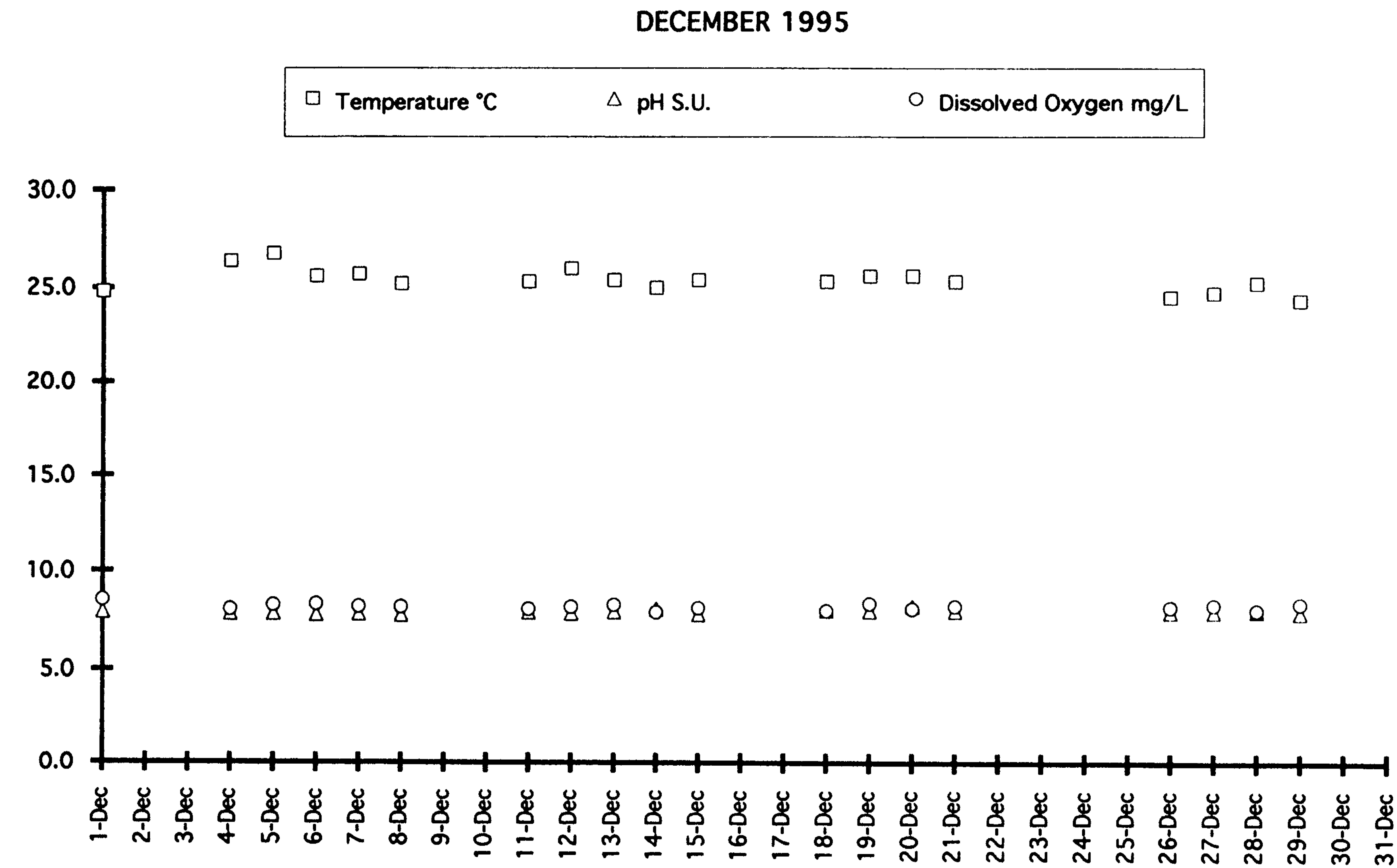

Figure 4-2.4m. Control water temperature, pH, and dissolved oxygen data obtained manually during December 1995.

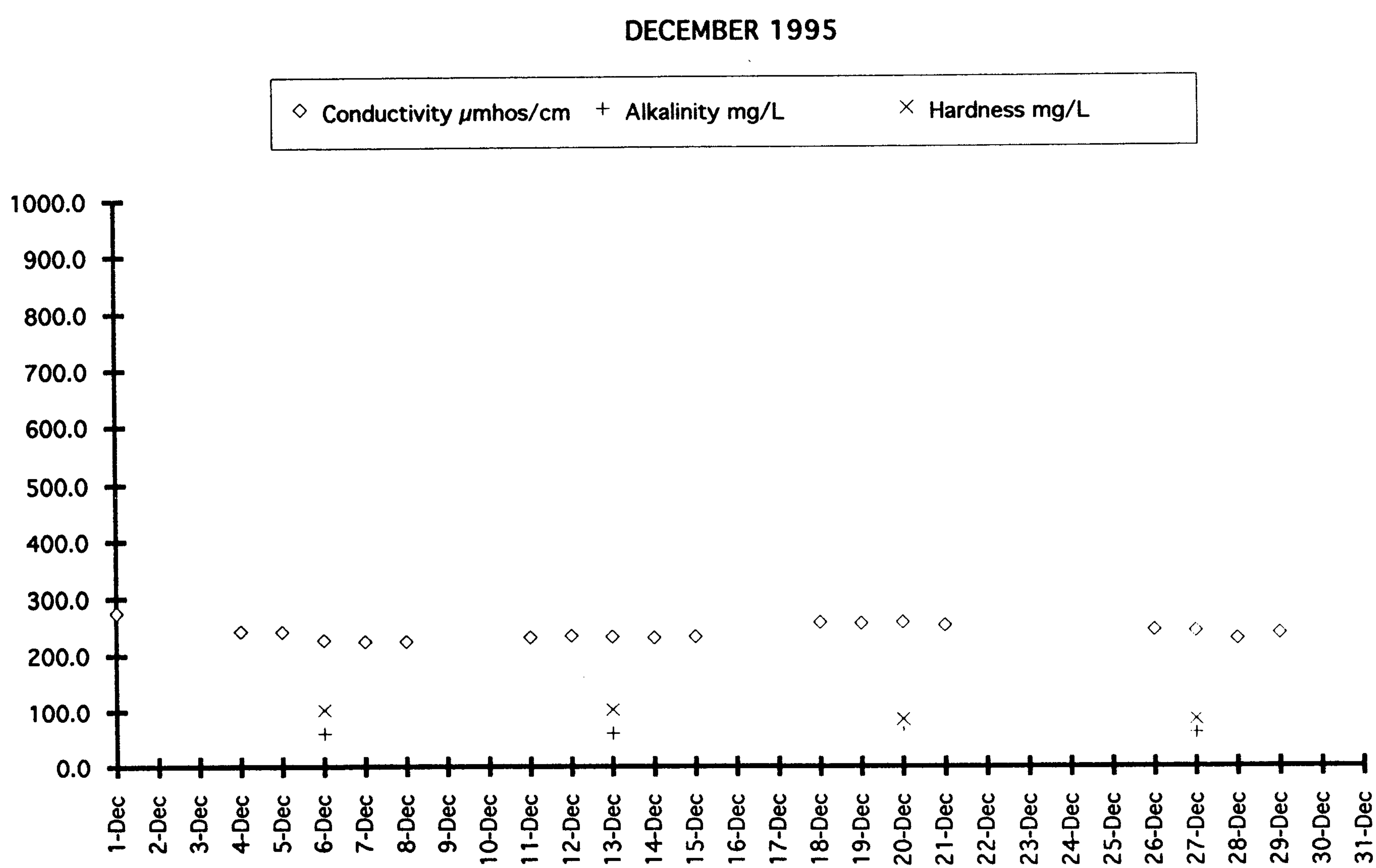

Figure 4-2.4n. Control water conductivity, alkalinity, and hardness data obtained manually during December 1995.

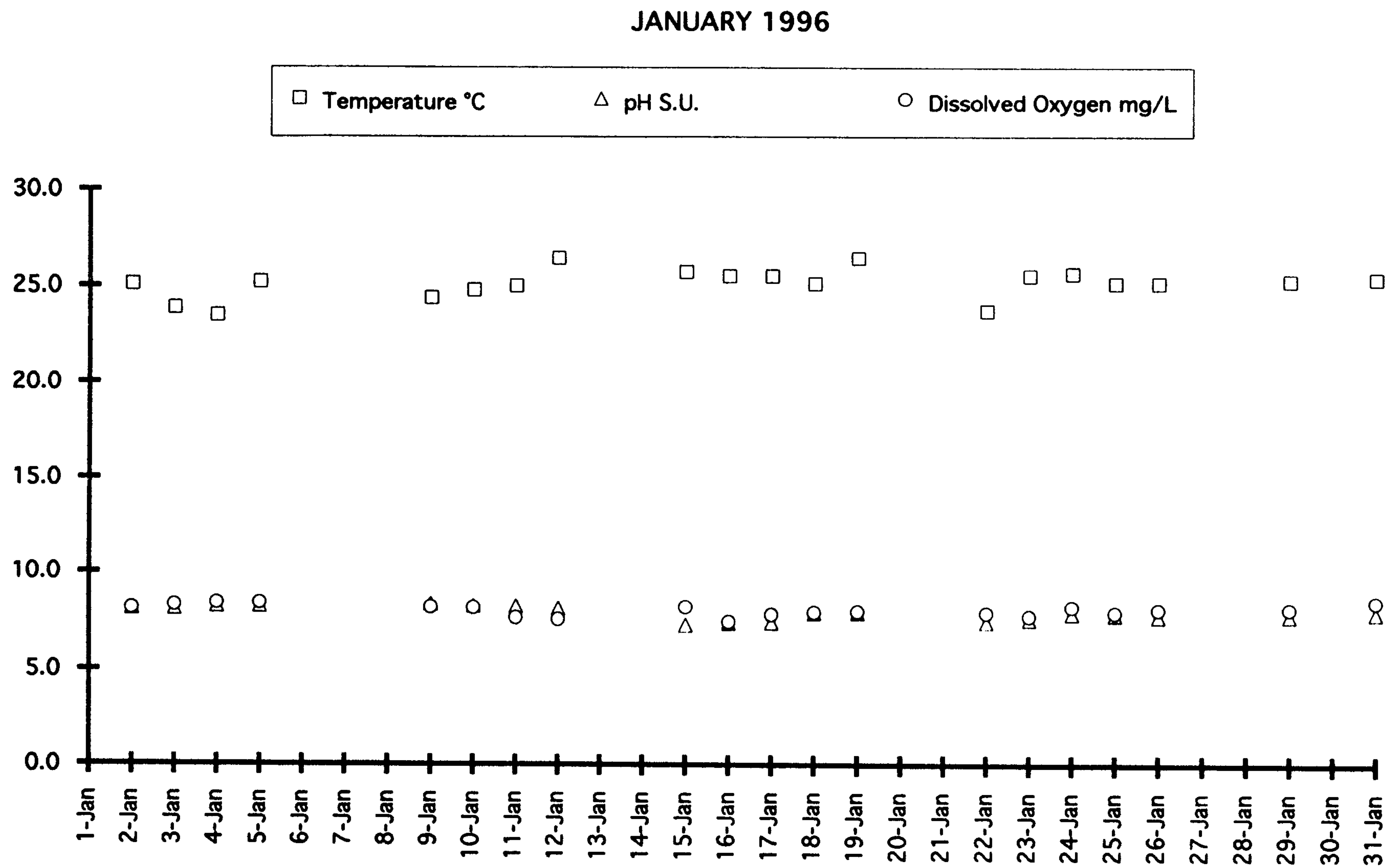

Figure 4-2.4o. Control water temperature, pH, and dissolved oxygen data obtained manually during January 1996.

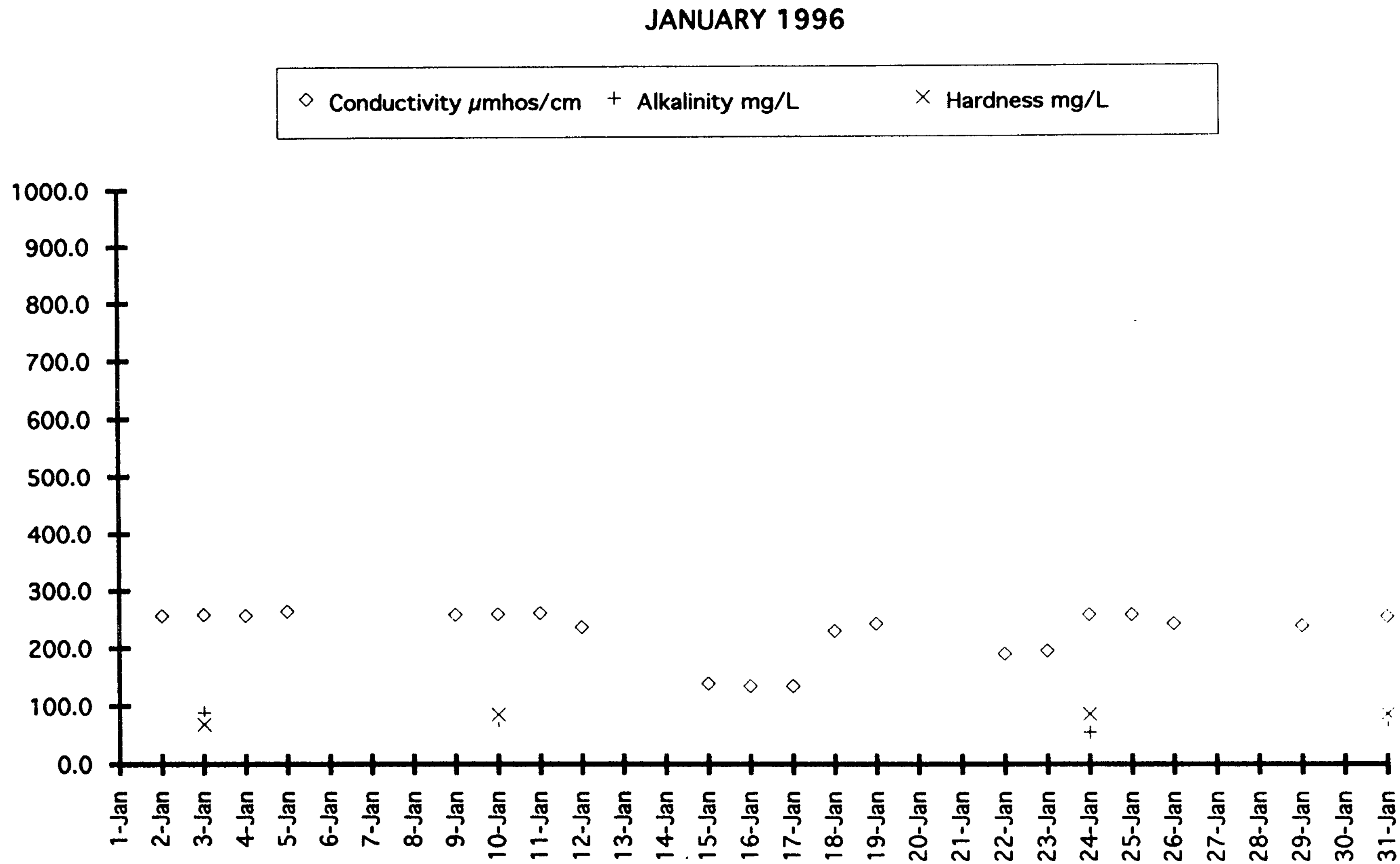

Figure 4-2.4p. Control water conductivity, alkalinity, and hardness data obtained manually during January 1996.

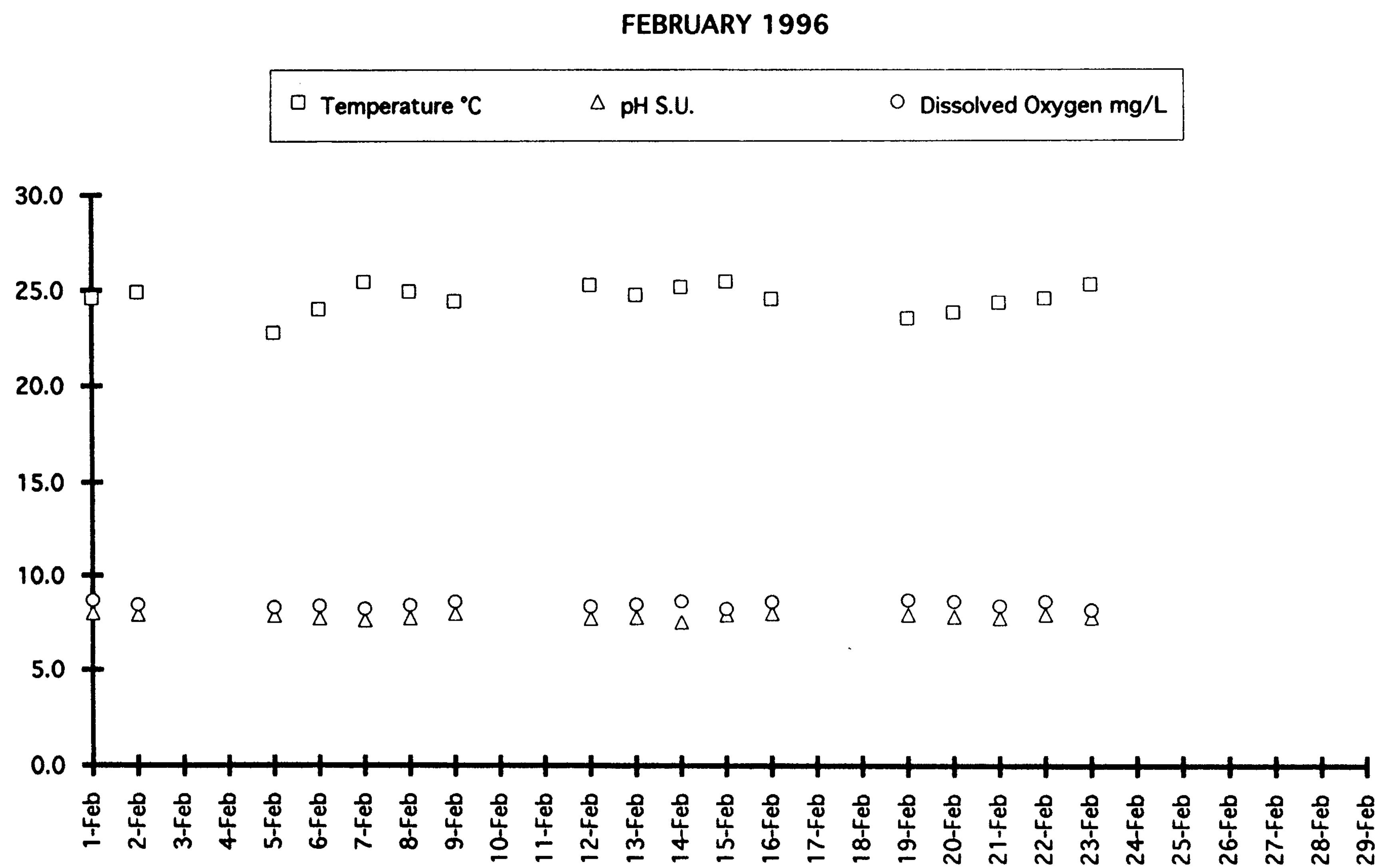

Figure 4-2.4q. Control water temperature, pH, and dissolved oxygen data obtained manually during February 1996.

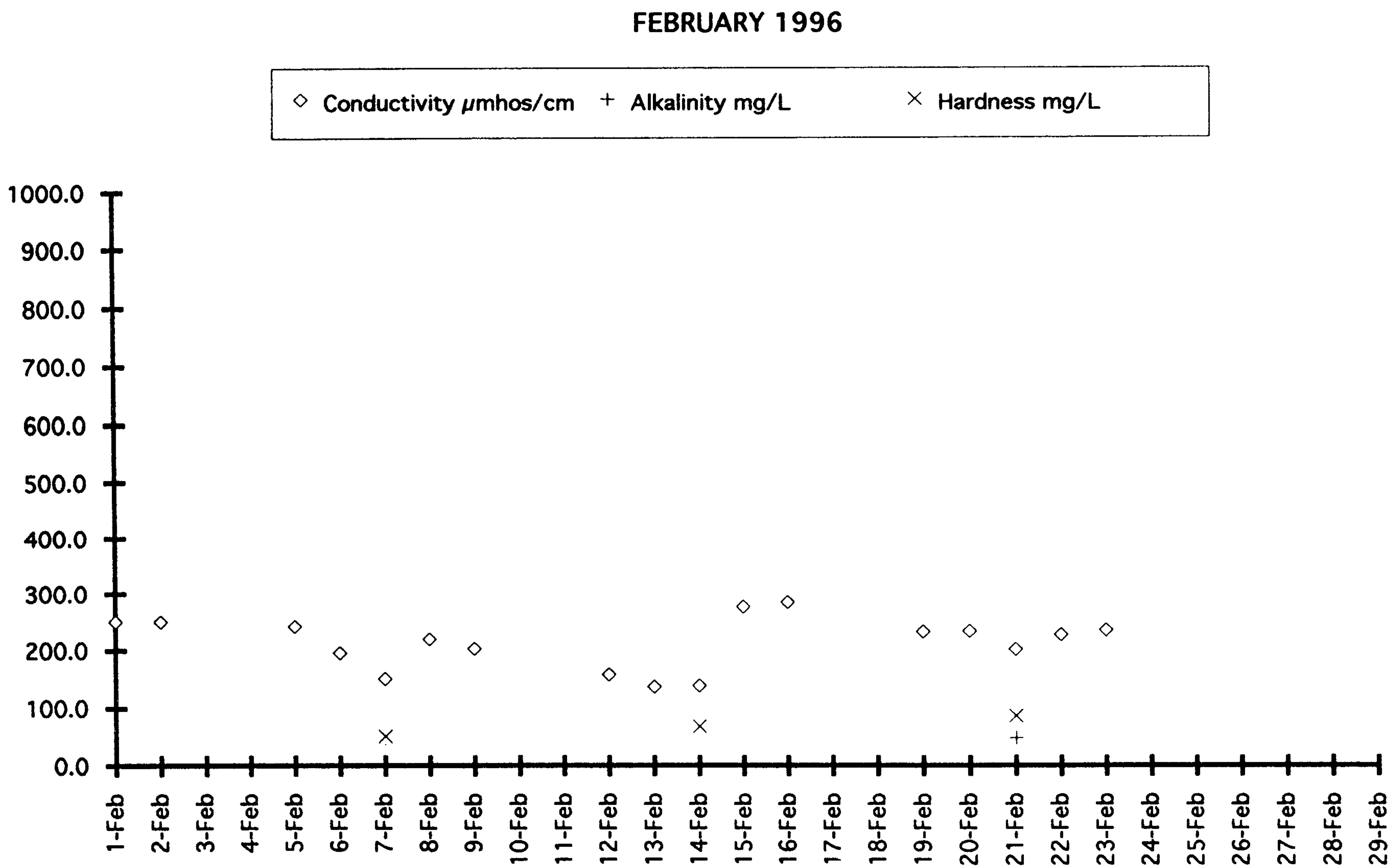

Figure 4-2.4r. Control water conductivity, alkalinity, and hardness data obtained manually during February 1996.

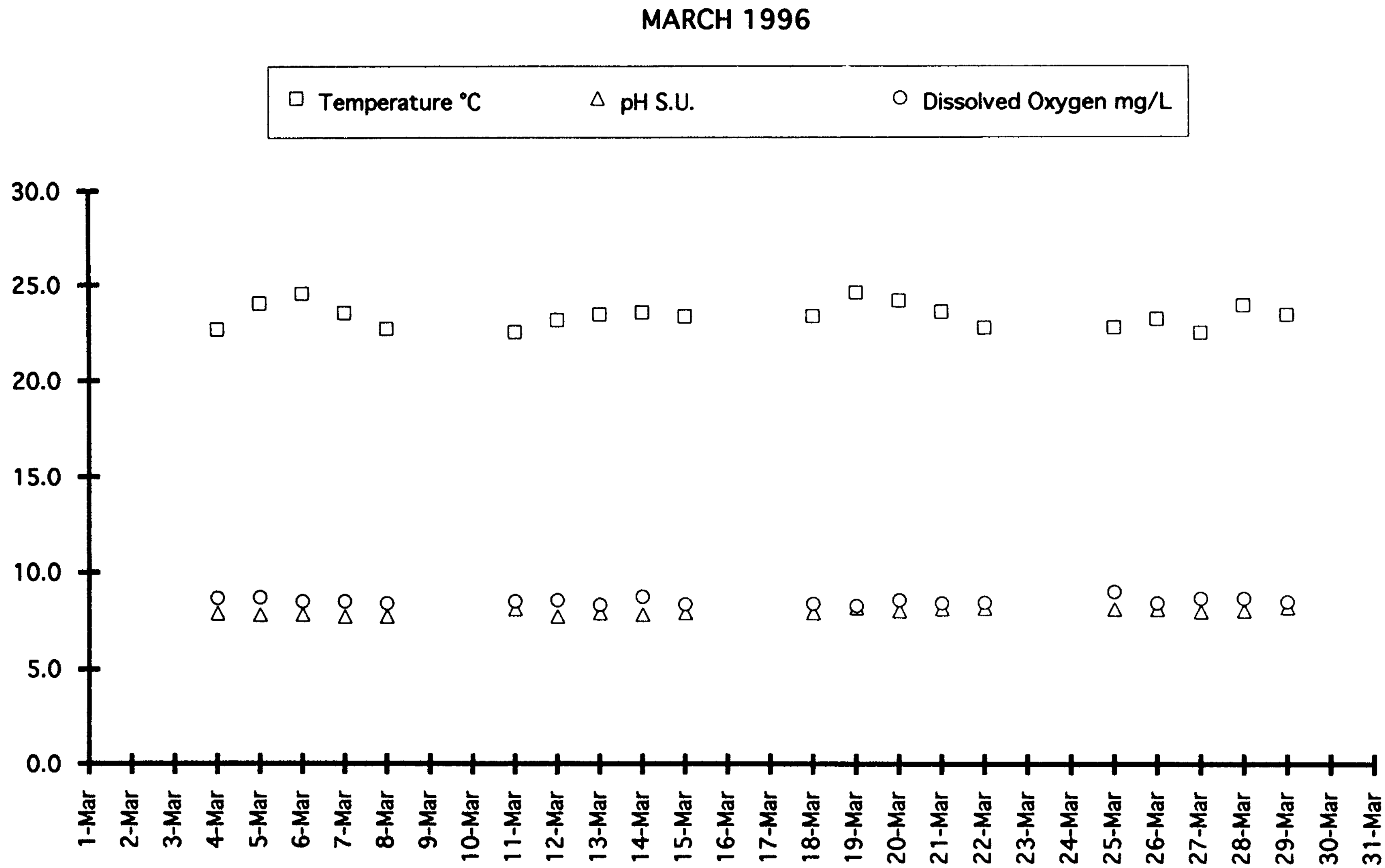

Figure 4-2.4s. Control water temperature, pH, and dissolved oxygen data obtained manually during March 1996.

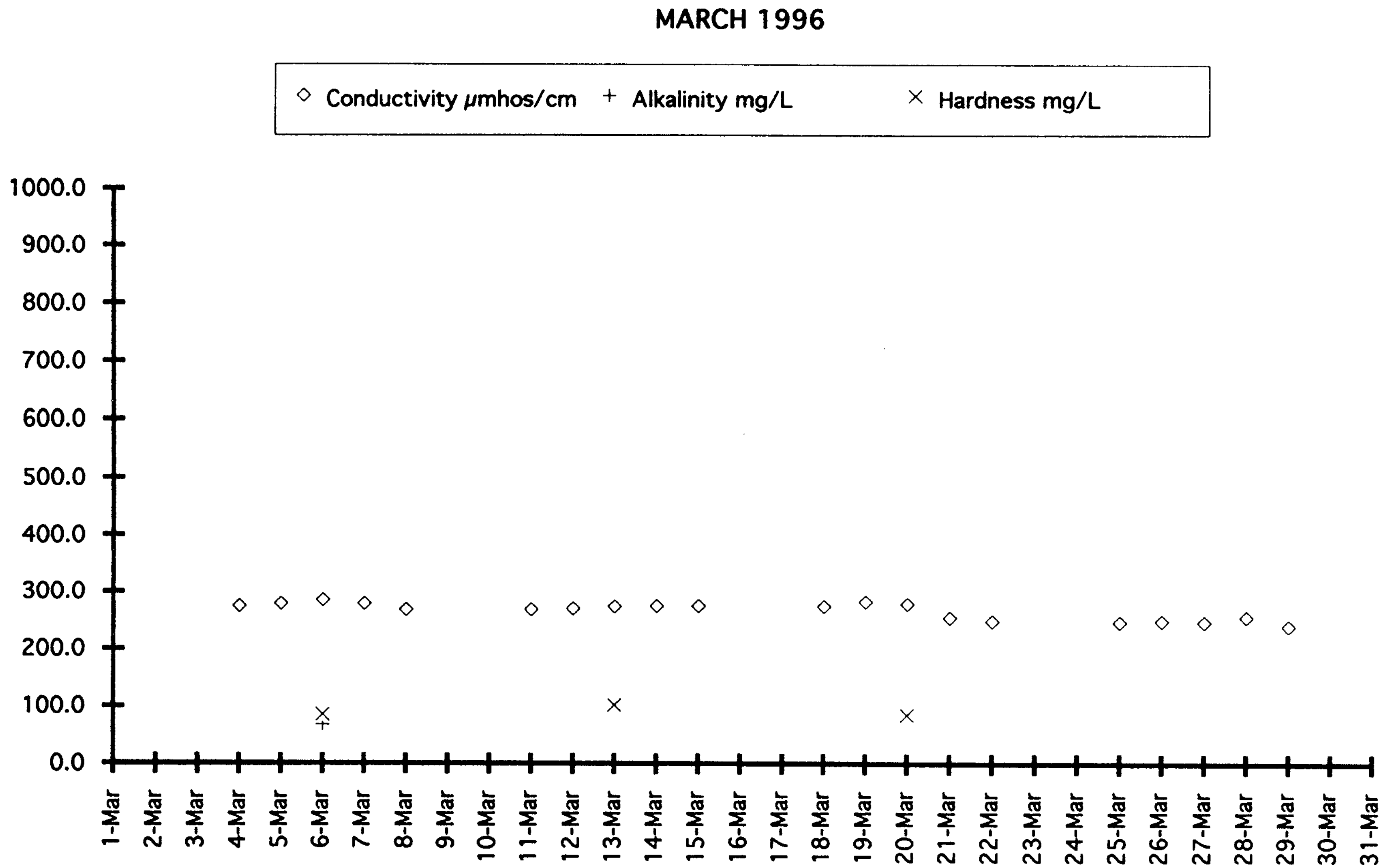

Figure 4-2.4t. Control water conductivity, alkalinity, and hardness data obtained manually during March 1996.

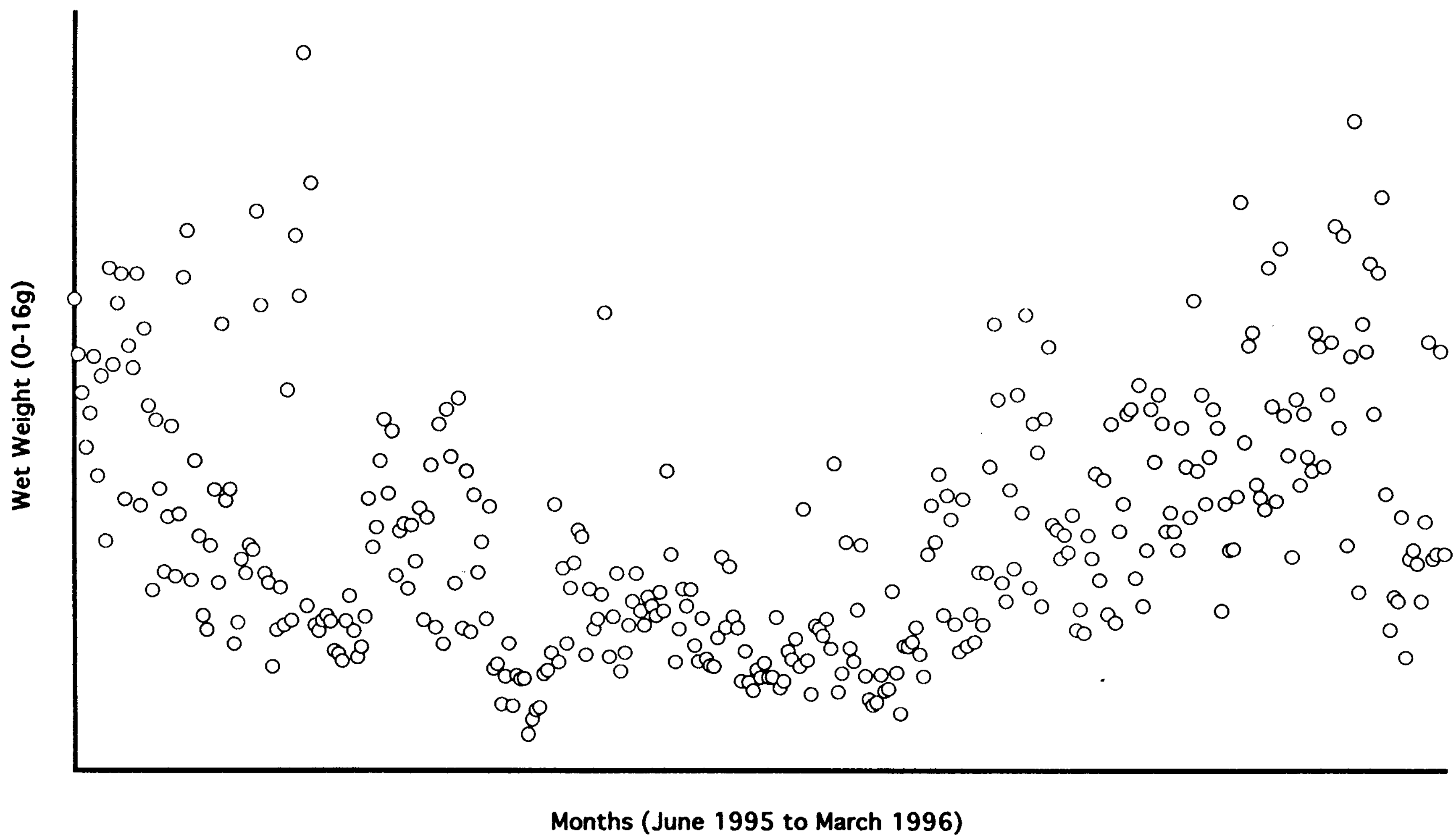

Figure 4-3a. Wet weight of effluent-exposed and control bluegills at end of each test.

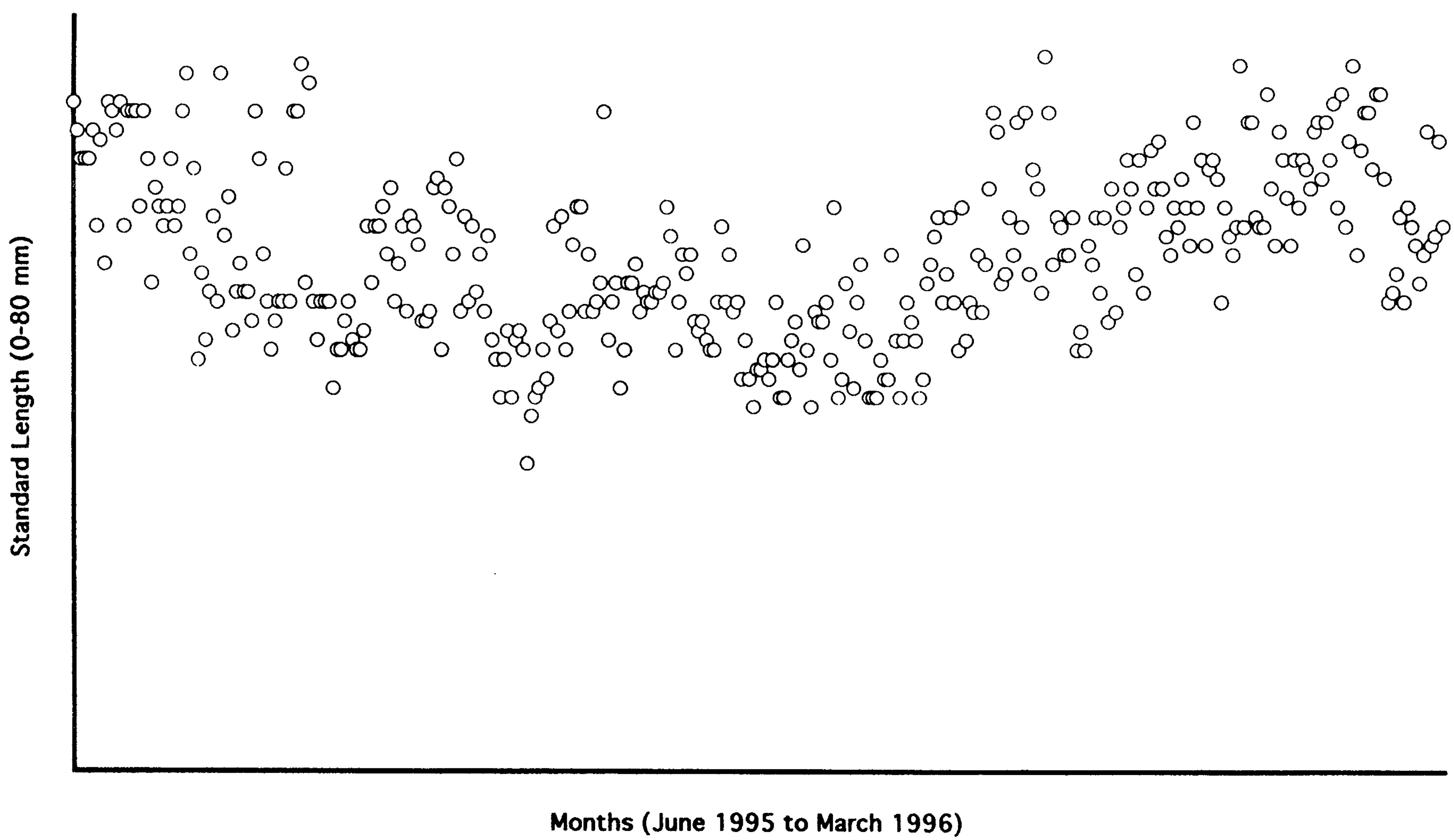

Figure 4-3b. Standard length of effluent-exposed and control bluegills at end of each test.

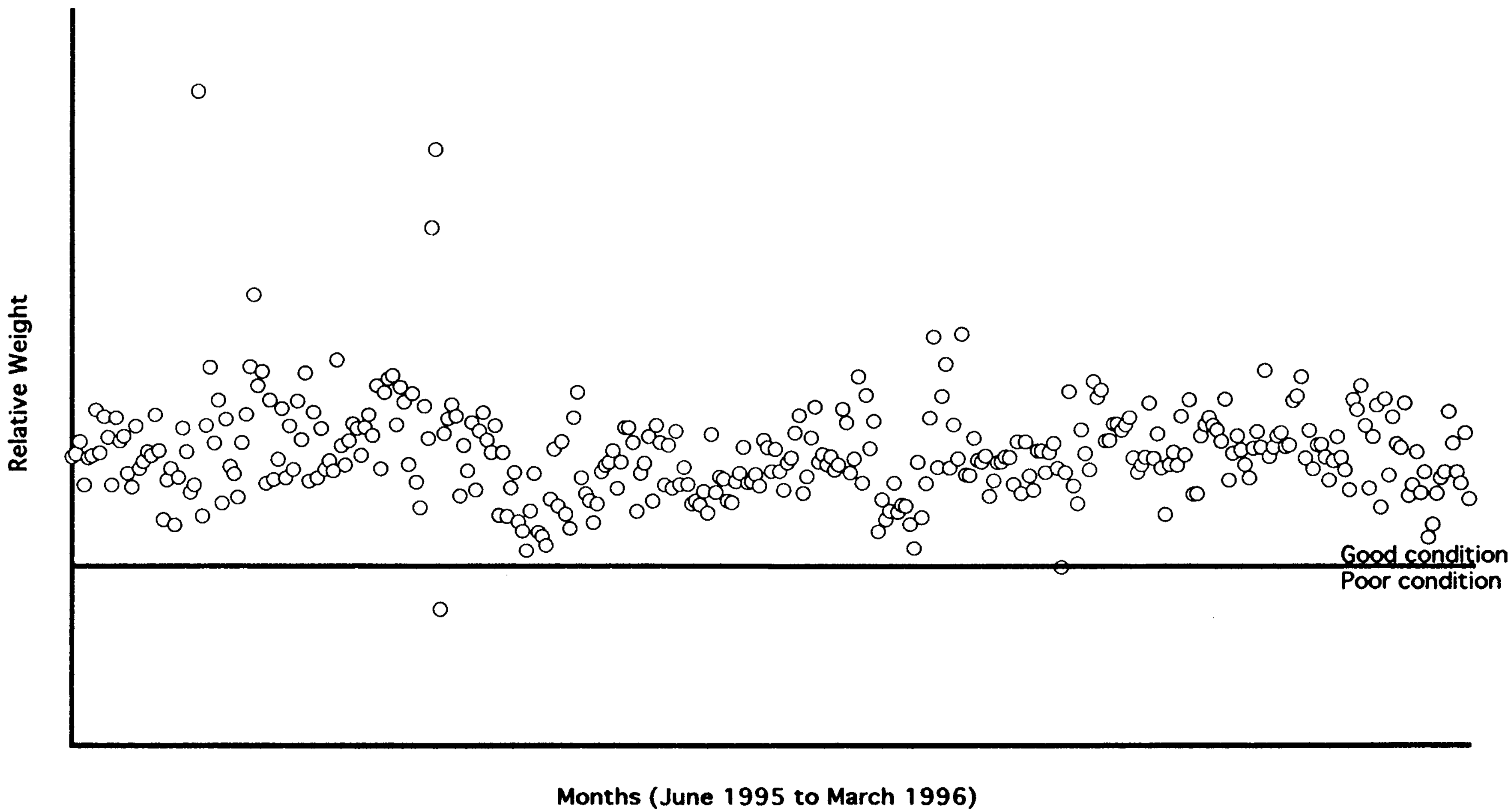

Figure 4-3c. Condition based on relative weights of effluent-exposed and control bluegills at end of each test.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Biomonitoring Responses

The Aquatic Biomonitoring Program data acquisition system was on-line for 272.9 d out of a total of 282.4 d. Data were not taken for 9.5 d because the data acquisition system was off-line for various reasons (e.g., Hydrolab® calibration, data transfer, program errors, etc.). The system was operated in an auxiliary mortality monitor mode for 17.4 d. No acute toxicity occurred from changes in effluent quality during the periods the system was operated as an auxiliary monitor mode.

A number of out of control events occurred during the operational period. The total number of days the system obtained out of control responses was 21.0 d when the system was on-line and was not in an auxiliary mortality monitor mode. Explanations for the out of control responses were available for 20.6 d of the 21.0 d. No obvious explanations were apparent for 0.5 d. The 0.1 d discrepancy between 20.6 d and 0.5 d is due to rounding error.

The out of control responses occurred from one of the following three reasons: 1) changes in effluent water quality; 2) power failures; or 3) a proportional diluter failure. Changes in effluent water quality accounted for 89.2% or 18.3 d of the total out of control responses with explanation. Loss of power and a diluter malfunction accounted for 5.9% and 4.9% of the out of control responses with explanation, respectively.

The majority of the out of control response events for which explanations were documented have been corrected and should not occur in the future. The water quality events which have been corrected (78.5% of the events) included 1) a high effluent conductivity problem; 2) a sudden drop in effluent temperature because the return line on the downstream aeration tank was not secured and the water in the tank passed to the drain rather than being recirculated and 3) responses caused by shifts in water quality when fish were switched from control water to effluent or effluent to control water. The remaining non-water quality out of control response events occurred as a result of 1) sustained losses of power because the GWTF backup generator did not start; the backup generator ran out of fuel; and/or power to the biomonitoring facility was interrupted and 2) the failure of a diluter. The majority of the backup generator failure problems can most likely be solved by appropriate GWTF maintenance and fueling of the generator. It is not clear how a future diluter failure can be eliminated since the diluters are routinely serviced and calibrated.

A few out of control responses occurred which did not have an apparent explanation. Out of control responses with no explanation occurred 0.2% of the time or 0.5 d during the period June 23, 1995 to March 31, 1996. A total of 16 events occurred. Twelve of the 16 events lasted 1 h or less. Three of the four events >1 h lasted 1.25 h; the fourth had a duration of 1.75 h. Five of the 16 out of control events occurred during the hours of 08:00 to 17:00 h. The remaining 11 occurred between the hours of 17:01 to 07:59 h.

Possible solutions for the out of control responses with no apparent explanation are not obvious. Twelve of the 16 out of control responses for which there was no apparent explanation lasted 1 h or less. It may be appropriate to evaluate whether or not events ≤1 h should be used as early warning indicators of potential GWTF toxicity. It may be possible to use some type of time series/neural network analyses to predict when the random events may occur. The evaluation should also consider whether or not the GWTF should stop discharging effluent during these short out of control periods, particularly, isolated 15-min events.

5.2 Effluent and Control Water Quality

Effluent and control water quality were continuously monitored by an in-line Hydrolab® system. The values generally fell within the ranges set in the Aquatic Ventilatory Program (i.e., temperature = 23-27°C from June 23, 1995 to February 29, 1996 and 21-25°C for March 1996; pH = 6.5-8.5 S.U.; and DO = 3-12 mg/L). However, a number of out of limit excursions occurred. The largest number of excursions occurred with temperature. With the exception of June in which no temperature excursions occurred, the out of limit excursions ranged from a low of 2% in March to a high of 46% in November. The temperature excursions can be reduced by instituting better control measures at the level of the two aeration tanks which are also used to regulate effluent and control water temperatures before they enter the ventilatory exposure system.

A number of pH excursions occurred in the effluent during the months of June, July and September; none occurred during the last two quarters of the study. It appears that pH excursions are not an on-going problem.

Out of limit DO excursions (outside the range of 3-12 mg/L) occurred during the months of June, July, and August. Several out of limit low DO readings occurred. In most of the cases, however, the DO excursions were above 12 mg/L. A number of the high readings approached an order of magnitude above saturation at 25°C. The excessively high values show that the oxygen sensor in the Hydrolab® system had 1) a recurring operational problem or 2) some material(s) present in the effluent may have interfered with the normal functioning of the probe. The high DO readings

were corrected by replacing the oxygen probe solution, membrane, and re-calibrating the sensor.

DO concentrations <5 mg/L trigger GWTF regulatory compliance actions. Out of compliance Hydrolab® DO readings occurred every month except November. In contrast, manually measured DO values were above 5 mg/L for all months except one reading in August; one reading in September; and five readings in March. The discrepancy between the Hydrolab® and manual DO reading needs to be resolved. Because of the large number of high and low (<5 mg/L) DO readings obtained by the Hydrolab® system relative to the small number of manual DO excursion readings, the operation of the Hydrolab® oxygen probe should be re-evaluated. Likewise, a number of "odd" conductivity measurements, which were corrected by re-calibrating the sensor, indicate that a problem also exists with the conductivity sensor.

In summary, a number of effluent water quality excursions occurred. However, with the exception of one low DO excursion caused by metabisulfite, none of the effluent water quality excursions appeared to be related to any out of control response events. No acute toxicity attributable to the GWTF effluent quality occurred during the period June 23, 1995 to March 31, 1996. An evaluation of the out of control response events <1 h in duration, for which there are no apparent explanations, should be conducted to determine whether or not the events should be used as early warning indicators of potential GWTF operational problems. Likewise, the performance of the Hydrolab® system, in particular the oxygen sensor, should be re-assessed to resolve the discrepancy between the Hydrolab® and manual DO readings.

SECTION 6

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APPENDIX 1

AVERAGE MONTHLY CONCENTRATIONS OF CONTAMINANTS IN OLD O-FIELD GROUNDWATER BEFORE AND AFTER TREATMENT AT THE OLD O-FIELD GROUNDWATER TREATMENT FACILITY

TABLE A1-1. AVERAGE MONTHLY CONCENTRATIONS OF THE CONTAMINANTS IN THE GROUNDWATER BEFORE AND AFTER TREATMENT AT THE GWTF (DEENY, 1996)[a]

	June		July		August		September		October		November		December	
Parameter	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Metals														
Arsenic	122.5	20.5	205	12.5	263	12	185	12.3	215	24	330	49	430	177
Lead	2.09	BQL	2.2	BQL	0.6	2.7	ND	BQL	ND	ND	5	ND	ND	ND
Aluminum	1,448	387	1,105	347	1,280	100	700	100	1,330	100	1,750	100	2,350	<100
Barium	46.05	24	53.5	31.7	56.8	40.9	59	40	105	55	86	47	65	27
Copper	236	41.9	300.5	35.8	320	10.6	266	BQL	670	BQL	708	20	435	ND
Iron	13,450	1,800	18,400	183.5	14,500	91	8,370	97	3E+05	BQL	22,250	ND	25,000	ND
Nickel	25.5	BQL	24	BQL	28.9	BQL	30	BQL	46	ND	36	ND	26	ND
Zinc	752	82.5	1,144	188	993	167	618	74.5	1,650	74.5	1,500	43	1,225	27
Conventionals														
TSS	20.5	14.2	18.5	12.5	43.9	5	27	10	22	1	37	3	35	1
Turbidity									63	0.9	90	0.4	68	0.3
TotalVOC's	5,545	15.5	9,320	18.1	8,321	5.9	9,660	ND	9,012	15	6,503	9.3	7,284	11.2
Chemical Surety Materials														
Thiodiglycol	426	ND	221	ND	25	ND		ND	10.5	ND	98.75	ND	7	ND
1,4-Dithiane	1,076	ND	1,064	BQL	2819	ND		ND	382.5	ND	53.8	ND	26	ND
1,4-Oxathiane	150.5	ND	161.5	BQL	79	ND		ND	26.5	ND	18.3	ND	9	ND
Thiodiglycol – Precursor														

TABLE A1-1. CONTINUED

	January		February		March	
Parameter	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Metals						
Arsenic	413	142	455	125	395	188
Lead	5	0.83	5	ND	ND	ND
Aluminum	6,375	122	6,200	140	4,800	135
Barium	62	20	57	19	49	15
Copper	540	7	680	5	795	7
Iron	29,750	50	29,000	ND	26,500	218
Nickel	40	3	41	ND	35	ND
Zinc	1,350	24	1,400	35	1,350	38
Conventionals						
TSS	125	3	26	1.5	46	1
Turbidity	87	0.5	39	0.4	56	0.7
TotalVOC's	6,031	15	7,690	22	8,532	25
Chemical Surety Materials						
Thiodiglycol	42.5	ND	13.5	ND	50	ND
1,4-Dithiane	1,680	ND	765.5	ND	343.7	ND
1,4-Oxathiane	255.5	ND	174	ND	37.25	ND
Thiodiglycol – Precursor						

[a]All units in ug/L except TSS in mg/L and Turbidity in NTU.

APPENDIX 2

STATISTICAL ANALYSES OF THE HYDROLAB® SYSTEM EFFLUENT WATER QUALITY DATA FROM JUNE 1995 TO MARCH 1996

TABLE A2-1. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF JUNE 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	24.5		6.0	598.2
Standard Error	0.05		0.09	17.52
Median	24.5		5.9	674.0
Mode	24.4		5.7	276.0
Standard Deviation	0.72		1.20	233.76
Variance	0.52		1.44	54644.32
Range	2.7		7.4	784.0
Minimum	23.2	7.0	4.6	197.0
Maximum	25.9	8.5	12.0	981.0
Count	178	164	168	178

TABLE A2-2. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF JULY 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	25.3		6.4	820.4
Standard Error	0.03		0.06	5.75
Median	25.3		5.9	840.0
Mode	25.1		5.8	812.0
Standard Deviation	0.74		1.46	155.32
Variance	0.55		2.14	24123.61
Range	3.6		8.1	1329.0
Minimum	23.4	6.9	3.8	281.0
Maximum	27.0	8.5	11.9	1610.0
Count	685	638	570	729

TABLE A2-3. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF AUGUST 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	25.4		5.8	894.3
Standard Error	0.03		0.05	7.91
Median	25.4		5.6	857.0
Mode	25.1		4.3	825.0
Standard Deviation	0.80		1.39	212.45
Variance	0.64		1.92	45135.50
Range	4.0		8.8	1818.0
Minimum	23.0	6.7	3.0	2.0
Maximum	27.0	8.3	11.8	1820.0
Count	664	721	670	721

TABLE A2-4. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF SEPTEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	24.3		6.6	1059.7
Standard Error	0.02		0.05	2.11
Median	24.4		6.1	1065.0
Mode	24.5		5.9	1094.0
Standard Deviation	0.56		1.43	55.79
Variance	0.32		2.04	3112.27
Range	2.9		7.3	290.0
Minimum	23.0	7.2	4.0	921.0
Maximum	25.9	8.5	11.3	1211.0
Count	676	618	696	696

TABLE A2-5. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF OCTOBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	24.0		6.3	1226.1
Standard Error	0.02		0.02	4.37
Median	24.0		6.2	1229.0
Mode	24.2		5.9	1045.0
Standard Deviation	0.54		0.59	111.15
Variance	0.29		0.35	12354.98
Range	2.2		3.7	1405.0
Minimum	23.0	7.1	4.4	5.0
Maximum	25.2	7.8	8.1	1410.0
Count	609	646	646	647

TABLE A2-6. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF NOVEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	23.7		6.0	1327.2
Standard Error	0.02		0.02	5.24
Median	23.6		6.0	1321.0
Mode	23.1		6.0	1500.0
Standard Deviation	0.47		0.42	139.48
Variance	0.22		0.17	19454.41
Range	1.9		2.3	411.0
Minimum	23.0	6.8	5.1	1139.0
Maximum	24.9	7.3	7.4	1550.0
Count	385	709	709	709

TABLE A2-7. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF DECEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
Mean	23.6		5.6	1052.3
Standard Error	0.02		0.03	3.67
Median	23.6		5.6	1084.0
Mode	23.1		5.8	1091.0
Standard Deviation	0.46		0.78	99.29
Variance	0.21		0.60	9857.62
Range	2.2		4.2	1146.0
Minimum	23.0	7.1	3.8	2.0
Maximum	25.2	8.3	8.0	1148.0
Count	540	732	732	732

TABLE A2-8. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF JANUARY 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
Mean	23.6		5.6	981.5
Standard Error	0.01		0.05	2.37
Median	23.6		5.6	992.0
Mode	23.4		5.2	956.0
Standard Deviation	0.27		1.31	63.78
Variance	0.07		1.72	4068.58
Range	1.2		7.3	420.0
Minimum	23.0	6.9	3.0	706.0
Maximum	24.2	7.6	10.4	1126.0
Count	427	726	725	726

TABLE A2-9. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF FEBRUARY 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	24.3		5.5	850.3
Standard Error	0.03		0.03	4.41
Median	24.3		5.4	862.0
Mode	23.6		5.2	876.0
Standard Deviation	0.70		0.86	115.47
Variance	0.49		0.74	13332.20
Range	2.6		6.8	1016.0
Minimum	23.0	6.9	3.7	3.0
Maximum	25.6	8.5	10.5	1019.0
Count	528	685	685	685

TABLE A2-10. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF MARCH 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	22.6		5.9	852.1
Standard Error	0.02		0.03	1.89
Median	22.6		6.0	848.0
Mode	22.8		6.8	872.0
Standard Deviation	0.54		0.84	48.62
Variance	0.29		0.71	2364.20
Range	3.4		4.0	337.0
Minimum	21.0	6.5	4.3	676.0
Maximum	24.5	8.1	8.3	1013.0
Count	645	661	661	661

APPENDIX 3

STATISTICAL ANALYSES OF THE MANUAL EFFLUENT WATER QUALITY DATA FROM JUNE 1995 TO MARCH 1996

TABLE A3-1. STATISTICAL ANALYSIS OF THE MANUAL EFFLUENT WATER QUALITY DATA DATA FOR THE MONTH OF JUNE 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	24.4		6.6	808.0
Standard Error	0.35		0.21	21.86
Median	24.4		6.6	803.0
Mode	#N/A		#N/A	#N/A
Standard Deviation	0.78		0.47	48.88
Variance	0.61		0.23	2389.00
Range	1.7		1.2	101.0
Minimum	23.6	6.8	6.0	760.0
Maximum	25.3	8.3	7.2	861.0
Count	5.0	5.0	5.0	5.0

TABLE A3-2. STATISTICAL ANALYSIS OF THE MANUAL EFFLUENT WATER QUALITY DATA FOR THE MONTH OF JULY 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	25.0		6.8	857.9	54.4	222.3
Standard Error	0.16		0.16	11.64	0.00	102.60
Median	25.0		6.8	846.0	54.4	222.3
Mode	25.0		6.8	#N/A	54.4	#N/A
Standard Deviation	0.70		0.71	50.73	0.00	145.10
Variance	0.50		0.51	2573.83	0.00	21053.52
Range	3.0		3.0	159.0	0.0	205.2
Minimum	23.6	7.1	5.7	794.0	54.4	119.7
Maximum	26.6	8.5	8.7	953.0	54.4	324.9
Count	19.0	19.0	19.0	19.0	2.0	2.0

TABLE A3-3. STATISTICAL ANALYSIS OF THE MANUAL EFFLUENT WATER QUALITY DATA FOR THE MONTH OF AUGUST 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	25.0		6.2	935.8	51.0	419.0
Standard Error	0.18		0.40	60.73	3.40	94.05
Median	25.0		6.3	888.0	51.0	419.0
Mode	24.2		6.5	#N/A	#N/A	#N/A
Standard Deviation	0.70		1.57	235.20	4.81	133.01
Variance	0.49		2.45	55320.74	23.12	17690.81
Range	2.1		7.3	947.0	6.8	188.1
Minimum	24.1	6.3	1.1	769.0	47.6	324.9
Maximum	26.2	8.1	8.4	1716.0	54.4	513.0
Count	15.0	14.0	15.0	15.0	2.0	2.0

TABLE A3-4. STATISTICAL ANALYSIS OF THE MANUAL EFFLUENT WATER QUALITY DATA FOR THE MONTH OF SEPTEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	24.0		6.2	1022.7	51.0	389.0
Standard Error	0.14		0.21	13.88	5.89	14.60
Median	24.1		6.6	1034.0	47.6	384.8
Mode	23.9		6.7	1083.0	47.6	#N/A
Standard Deviation	0.59		0.90	58.88	11.78	29.20
Variance	0.35		0.81	3467.39	138.72	852.86
Range	2.5		3.8	196.0	27.2	68.4
Minimum	22.4	7.4	3.4	900.0	40.8	359.1
Maximum	24.9	9.1	7.2	1096.0	68.0	427.5
Count	18.0	18.0	18.0	18.0	4.0	4.0

TABLE A3-5. STATISTICAL ANALYSIS OF THE MANUAL EFFLUENT WATER QUALITY DATA FOR THE MONTH OF OCTOBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	23.8		6.6	1220.4	36.3	364.8
Standard Error	0.14		0.16	18.97	8.17	11.40
Median	23.7		6.5	1199.0	40.8	376.2
Mode	23.7		6.2	#N/A	#N/A	376.2
Standard Deviation	0.60		0.68	82.68	14.16	19.75
Variance	0.36		0.46	6835.58	200.37	389.88
Range	2.1		2.4	302.0	27.2	34.2
Minimum	22.8	7.1	5.6	1048.0	20.4	342.0
Maximum	24.9	7.9	8.0	1350.0	47.6	376.2
Count	19.0	18.0	19.0	19.0	3.0	3.0

TABLE A3-6. STATISTICAL ANALYSIS OF THE MANUAL EFFLUENT WATER QUALITY DATA FOR THE MONTH OF NOVEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	23.2		6.3	1311.6	54.4	335.2
Standard Error	0.18		0.08	26.63	11.97	69.80
Median	23.2		6.3	1316.5	40.8	376.2
Mode	23.5		6.4	1497.0	40.8	#N/A
Standard Deviation	0.83		0.37	119.08	26.77	156.07
Variance	0.68		0.14	14179.94	716.72	24357.75
Range	2.9		1.4	367.0	61.2	410.4
Minimum	21.7	6.9	5.8	1155.0	40.8	68.4
Maximum	24.6	8.1	7.2	1522.0	102.0	478.8
Count	20.0	19.0	20.0	20.0	5.0	5.0

TABLE A3-7. STATISTICAL ANALYSIS OF THE MANUAL EFFLUENT WATER QUALITY DATA FOR THE MONTH OF DECEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	23.6		6.3	1043.6	40.8	359.1
Standard Error	0.14		0.13	14.34	2.78	13.96
Median	23.7		6.4	1040.5	40.8	359.1
Mode	24.0		6.5	1018.0	40.8	359.1
Standard Deviation	0.61		0.57	64.14	5.55	27.92
Variance	0.37		0.33	4114.37	30.83	779.76
Range	2.2		1.9	248.0	13.6	68.4
Minimum	22.4	7.0	5.4	910.0	34.0	324.9
Maximum	24.6	7.3	7.3	1158.0	47.6	393.3
Count	20.0	20.0	20.0	20.0	4.0	4.0

TABLE A3-8. STATISTICAL ANALYSIS OF THE MANUAL EFFLUENT WATER QUALITY DATA FOR THE MONTH OF JANUARY 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	23.2		6.1	973.1	44.2	350.6
Standard Error	0.20		0.11	11.11	1.96	8.55
Median	23.4		6.0	980.0	44.2	342.0
Mode	23.4		6.0	980.0	40.8	342.0
Standard Deviation	0.93		0.52	50.93	3.93	17.10
Variance	0.86		0.27	2594.09	15.41	292.41
Range	3.4		2.2	231.0	6.8	34.2
Minimum	21.2	6.9	5.4	834.0	40.8	342.0
Maximum	24.6	7.8	7.5	1065.0	47.6	376.2
Count	21.0	21.0	21.0	21.0	4.0	4.0

TABLE A3-9. STATISTICAL ANALYSIS OF THE MANUAL EFFLUENT WATER QUALITY DATA FOR THE MONTH OF FEBRUARY 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	23.9		6.1	932.1	41.5	303.5
Standard Error	0.29		0.15	10.03	2.22	40.33
Median	24.3		5.9	935.0	40.8	333.5
Mode	23.4		#N/A	#N/A	40.8	359.1
Standard Deviation	1.34		0.67	45.99	4.45	80.66
Variance	1.78		0.45	2115.13	19.78	6506.12
Range	5.5		3.0	195.0	10.7	171.0
Minimum	19.7	6.9	5.2	830.0	36.9	188.1
Maximum	25.2	7.7	8.1	1025.0	47.6	359.1
Count	21.0	21.0	21.0	21.0	4.0	4.0

TABLE A3-10. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF MARCH 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	23.2		5.6	857.3	40.8	312.9
Standard Error	0.14		0.19	7.90	#N/A	11.97
Median	23.1		5.8	862.0	40.8	324.9
Mode	22.7		6.2	853.0	#N/A	324.9
Standard Deviation	0.62		0.87	36.20	#DIV/0	20.73
Variance	0.39		0.76	1310.43	#DIV/0	429.60
Range	2.3		4.2	132.0	0.0	35.9
Minimum	22.2	6.8	3.5	776.0	40.8	289.0
Maximum	24.5	7.3	7.7	908.0	40.8	324.9
Count	21.0	21.0	21.0	21.0	1.0	3.0

APPENDIX 4

STATISTICAL ANALYSES OF THE HYDROLAB® SYSTEM CONTROL WATER QUALITY DATA FROM JUNE 1995 TO MARCH 1996

TABLE A4-1. STATISTICAL ANALYSES OF HYDROLAB SYSTEM CONTROL WATER QUALITY FOR THE MONTH OF JUNE 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	25.0		8.1	194.0
Standard Error	0.06		0.02	4.32
Median	25.1		8.1	216.0
Mode	25.5		8.1	225.0
Standard Deviation	0.80		0.28	54.09
Variance	0.64		0.08	2926.11
Range	2.7		2.1	282.0
Minimum	23.6	8.1	6.8	101.0
Maximum	26.3	8.6	8.9	383.0
Count	178	178	178	157

TABLE A4-2. STATISTICAL ANALYSES OF HYDROLAB SYSTEM CONTROL WATER QUALITY FOR THE MONTH OF JULY 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	25.7		7.9	249.6
Standard Error	0.03		0.05	4.42
Median	25.8		8.0	244.0
Mode	26.2		8.2	245.0
Standard Deviation	0.72		1.08	118.26
Variance	0.51		1.16	13984.98
Range	3.3		6.8	794.0
Minimum	23.7	6.3	5.0	100.0
Maximum	27.0	8.7	11.8	894.0
Count	652	730	575	716

TABLE A4-3. STATISTICAL ANALYSES OF HYDROLAB SYSTEM CONTROL WATER QUALITY FOR THE MONTH OF AUGUST 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
Mean	25.4		7.4	228.6
Standard Error	0.03		0.04	4.46
Median	25.6		7.5	210.0
Mode	25.9		7.4	196.0
Standard Deviation	0.84		1.04	119.40
Variance	0.71		1.08	14256.41
Range	3.8		5.3	748.0
Minimum	23.2	6.3	4.9	146.0
Maximum	27.0	8.5	10.2	894.0
Count	614	720	650	718

TABLE A4-4. STATISTICAL ANALYSES OF HYDROLAB SYSTEM CONTROL WATER QUALITY FOR THE MONTH OF SEPTEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
Mean	24.3		8.0	229.6
Standard Error	0.02		0.02	0.48
Median	24.3		7.9	232.0
Mode	24.3		8.1	232.0
Standard Deviation	0.43		0.60	12.58
Variance	0.19		0.36	158.24
Range	2.5		2.9	76.0
Minimum	23.1	7.8	7.0	193.0
Maximum	25.6	8.2	9.9	269.0
Count	676	695	695	695

TABLE A4-5. STATISTICAL ANALYSES OF HYDROLAB SYSTEM CONTROL WATER QUALITY FOR THE MONTH OF OCTOBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
Mean	24.9		8.1	271.3
Standard Error	0.03		0.01	1.31
Median	24.8		8.0	270.0
Mode	24.9		8.0	270.0
Standard Deviation	0.65		0.24	34.85
Variance	0.42		0.06	1214.73
Range	3.9		4.7	650.0
Minimum	23.1	7.7	4.0	247.0
Maximum	27.0	8.6	8.7	897.0
Count	643	711	711	710

TABLE A4-6. STATISTICAL ANALYSES OF HYDROLAB SYSTEM CONTROL WATER QUALITY FOR THE MONTH OF NOVEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
Mean	24.9		8.1	271.3
Standard Error	0.03		0.01	1.31
Median	24.8		8.0	270.0
Mode	24.9		8.0	270.0
Standard Deviation	0.65		0.24	34.85
Variance	0.42		0.06	1214.73
Range	3.9		4.7	650.0
Minimum	23.1	7.7	4.0	247.0
Maximum	27.0	8.6	8.7	897.0
Count	643	711	711	710

TABLE A4-7. STATISTICAL ANALYSES OF HYDROLAB SYSTEM CONTROL WATER QUALITY FOR THE MONTH OF DECEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	25.8		7.7	241.4
Standard Error	0.02		0.01	0.47
Median	25.8		7.7	243.0
Mode	25.6		7.4	228.0
Standard Deviation	0.48		0.26	12.79
Variance	0.23		0.07	163.57
Range	2.7		2.2	54.0
Minimum	24.3	7.9	6.1	219.0
Maximum	27.0	8.3	8.3	273.0
Count	716	734	734	734

TABLE A4-8. STATISTICAL ANALYSES OF HYDROLAB SYSTEM CONTROL WATER QUALITY FOR THE MONTH OF JANUARY 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	25.6		7.1	222.7
Standard Error	0.03		0.06	1.80
Median	25.8		7.7	239.0
Mode	25.8		8.3	260.0
Standard Deviation	0.78		1.63	48.90
Variance	0.61		2.65	2388.00
Range	3.3		7.5	385.0
Minimum	23.8	7.4	3.4	128.0
Maximum	27.0	8.5	10.9	513.0
Count	709	727	727	727

TABLE A4-9. STATISTICAL ANALYSES OF HYDROLAB SYSTEM CONTROL WATER QUALITY FOR THE MONTH OF FEBRUARY 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
Mean	24.8		8.3	239.0
Standard Error	0.03		0.04	3.45
Median	24.9		8.2	225.0
Mode	24.6		8.1	268.0
Standard Deviation	0.85		1.10	88.20
Variance	0.72		1.22	7779.44
Range	4.0		7.2	798.0
Minimum	23.0	7.2	3.4	127.0
Maximum	27.0	8.5	10.6	925.0
Count	594	619	685	654

TABLE A4-10. STATISTICAL ANALYSES OF HYDROLAB SYSTEM EFFLUENT WATER QUALITY FOR THE MONTH OF MARCH 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
Mean	23.5		8.4	263.3
Standard Error	0.02		0.01	0.58
Median	23.5		8.5	268.0
Mode	23.6		8.4	277.0
Standard Deviation	0.56		0.37	14.92
Variance	0.32		0.14	222.65
Range	3.9		2.4	90.0
Minimum	21.0	7.6	6.6	191.0
Maximum	24.9	8.3	9.0	281.0
Count	647	651	661	661

APPENDIX 5

STATISTICAL ANALYSES OF THE MANUAL CONTROL WATER QUALITY DATA FROM JUNE 1995 TO MARCH 1996

TABLE A5-1. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF JUNE 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
Mean	24.9		8.5	243.0
Standard Error	0.25		0.10	2.52
Median	24.9		8.6	243.5
Mode	#N/A		8.7	#N/A
Standard Deviation	0.62		0.24	6.17
Variance	0.38		0.06	38.10
Range	1.6		0.6	12.7
Minimum	24.3	7.7	8.1	236.0
Maximum	25.9	7.9	8.7	248.7
Count	6.0	6.0	6.0	6.0

TABLE A5-2. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF JULY 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	25.5		8.3	243.4	61.2	102.6
Standard Error	0.21		0.05	2.42	0.00	0.00
Median	25.8		8.3	246.8	61.2	102.6
Mode	26.3		8.2	220.0	61.2	102.6
Standard Deviation	0.94		0.21	10.54	0.00	0.00
Variance	0.87		0.05	111.18	0.00	0.00
Range	3.3		1.0	31.0	0.0	0.0
Minimum	24.1	7.7	7.8	220.0	61.2	102.6
Maximum	27.4	8.6	8.8	251.0	61.2	102.6
Count	19.0	19.0	18.0	19.0	2.0	2.0

TABLE A5-3. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF AUGUST 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	25.0		8.2	206.4	51.0	85.5
Standard Error	0.20		0.05	5.89	3.40	0.00
Median	24.7		8.2	220.1	54.4	85.5
Mode	24.2		8.2	#N/A	54.4	85.5
Standard Deviation	0.95		0.22	27.63	6.80	0.00
Variance	0.91		0.05	763.51	46.24	0.00
Range	3.7		0.9	81.0	13.6	0.0
Minimum	23.3	6.0	7.8	149.7	40.8	85.5
Maximum	27.0	8.1	8.7	230.7	54.4	85.5
Count	22.0	21.0	22.0	22.0	4.0	4.0

TABLE A5-4. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF SEPTEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	24.1		8.2	230.6	57.1	82.1
Standard Error	0.12		0.04	2.10	3.47	3.42
Median	24.2		8.2	231.2	54.4	85.5
Mode	24.1		8.1	228.8	54.4	85.5
Standard Deviation	0.55		0.19	9.38	7.75	7.65
Variance	0.30		0.03	87.90	60.11	58.48
Range	2.1		0.7	37.1	20.4	17.1
Minimum	22.6	7.9	7.9	207.9	47.6	68.4
Maximum	24.7	8.2	8.6	245.0	68.0	85.5
Count	20.0	20.0	20.0	20.0	5.0	5.0

TABLE A5-5. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF OCTOBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	24.4		8.3	237.5	54.4	85.5
Standard Error	0.12		0.03	4.94	3.93	0.00
Median	24.5		8.3	240.1	54.4	85.5
Mode	24.2		8.4	271.3	#N/A	85.5
Standard Deviation	0.55		0.12	22.64	6.80	0.00
Variance	0.30		0.01	512.73	46.24	0.00
Range	2.6		0.5	60.3	13.6	0.0
Minimum	22.9	7.7	8.0	211.0	47.6	85.5
Maximum	25.5	8.1	8.5	271.3	61.2	85.5
Count	21.0	20.0	21.0	21.0	3.0	3.0

TABLE A5-6. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF NOVEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	25.1		8.1	273.9	86.0	75.2
Standard Error	0.22		0.06	2.43	5.47	4.19
Median	24.9		8.2	275.9	88.4	68.4
Mode	25.2		8.2	276.1	88.4	68.4
Standard Deviation	0.97		0.28	10.86	12.23	9.37
Variance	0.95		0.08	117.89	149.57	87.72
Range	3.2		1.1	40.2	34.0	17.1
Minimum	24.0	7.8	7.6	252.3	68.0	68.4
Maximum	27.2	8.1	8.7	292.5	102.0	85.5
Count	20.0	19.0	20.0	20.0	5.0	5.0

TABLE A5-7. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF DECEMBER 1995

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	25.4		8.2	240.1	64.6	94.1
Standard Error	0.14		0.03	3.16	3.40	4.94
Median	25.3		8.2	236.5	61.2	94.1
Mode	25.3		8.3	257.3	61.2	85.5
Standard Deviation	0.61		0.14	13.75	6.80	9.87
Variance	0.37		0.02	189.18	46.24	97.47
Range	2.5		0.6	51.3	13.6	17.1
Minimum	24.3	7.8	7.9	223.8	61.2	85.5
Maximum	26.8	8.2	8.5	275.1	74.8	102.6
Count	19.0	19.0	19.0	19.0	4.0	4.0

TABLE A5-8. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF JANUARY 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	25.1		8.0	227.5	73.1	81.2
Standard Error	0.17		0.06	10.04	7.01	4.28
Median	25.2		8.1	247.1	74.8	85.5
Mode	25.1		8.1	#N/A	74.8	85.5
Standard Deviation	0.76		0.28	44.88	14.02	8.55
Variance	0.58		0.08	2014.39	196.52	73.10
Range	2.9		1.0	130.9	34.0	17.1
Minimum	23.5	7.3	7.5	133.1	54.4	68.4
Maximum	26.4	8.3	8.5	264.0	88.4	85.5
Count	20.0	20.0	20.0	20.0	4.0	4.0

TABLE A5-9. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF FEBRUARY 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	24.5		8.4	213.4	54.4	68.4
Standard Error	0.17		0.04	10.99	6.80	9.87
Median	24.6		8.4	226.5	47.6	68.4
Mode	24.5		8.6	#N/A	47.6	#N/A
Standard Deviation	0.71		0.17	45.32	11.78	17.10
Variance	0.50		0.03	2053.79	138.72	292.41
Range	2.6		0.6	146.3	20.4	34.2
Minimum	22.8	7.5	8.1	136.9	47.6	51.3
Maximum	25.4	8.0	8.7	283.2	68.0	85.5
Count	17.0	17.0	17.0	17.0	3.0	3.0

TABLE A5-10. STATISTICAL ANALYSIS OF THE MANUAL CONTROL WATER QUALITY DATA FOR THE MONTH OF MARCH 1996

Statistic	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Alkalinity (mg/L)	Hardness (mg/L)
Mean	23.3		8.5	265.8	68.0	91.2
Standard Error	0.14		0.04	3.14	#N/A	5.70
Median	23.3		8.5	271.9	68.0	85.5
Mode	22.7		8.4	#N/A	#N/A	85.5
Standard Deviation	0.62		0.18	14.06	#DIV/0	9.87
Variance	0.39		0.03	197.68	#DIV/0	97.47
Range	2.1		0.7	45.3	0.0	17.1
Minimum	22.4	7.7	8.3	239.6	68.0	85.5
Maximum	24.5	8.2	9.0	284.9	68.0	102.6
Count	20.0	20.0	20.0	20.0	1.0	3.0

APPENDIX 6

USABRDL TRACE METAL ANALYSES OF EFFLUENT TAKEN DURING OUT OF CONTROL RESPONSES FROM JUNE 1995 TO MARCH 1996

TABLE A6-1. USDABRDL TRACE METAL ANALYSIS OF OLD O-FIELD GWTF EFFLUENT TAKEN DURING VARIOUS OUT OF CONTROL RESPONSE EVENTS FROM JUNE 1995 TO MARCH 1996[a]

		VALUES REPORTED IN PPB				* VALUES REPORTED IN PPM																							
DATE	TIME	Li	Be	Mg *	Al	Ca *	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Mo	Ag	Cd	Sb	Cs	Ba	Hg	Tl	Pb	U
6-26-95	13:52	XXX	BDL	16	550	93.97	BDL	BDL	180	820	BDL	BDL	BDL	110	XXX	BDL	BDL	XXX	XXX	BDL	BDL	BDL	BDL	XXX	BDL	BDL	BDL	BDL	XXX
6-30-95	09:07	NOT ANALYZED (POWER LOSS)																											
7-1-95	03:52	NOT ANALYZED (POWER LOSS)																											
7-21-95	06:15	NOT ANALYZED (POWER LOSS)																											
7-28-95	13:24	65.2	BDL	11.1	112	90.5	11.5	34.5	333.4	809.1	3.6	7.3	13.2	119.8	1.6	49	7.5	5.5	204.5	XXX	XXX	0.7	XXX	BDL	XXX	BDL	1.1	BDL	BDL
7-29-95	01:39	73.8	BDL	11.9	103.3	95.8	10.7	32.8	346.9	882.5	3.9	8.1	14.9	120.9	1.6	50.5	7.6	5.8	214.7	XXX	XXX	0.7	XXX	BDL	XXX	BDL	BDL	0.8	BDL
7-29-95	04:09	111.4	BDL	12.8	146.9	102.4	13.9	41.8	381.9	1022.7	4.3	10.9	16.7	154.8	2.3	57.4	10.3	7.2	248.6	XXX	XXX	1.1	XXX	BDL	XXX	BDL	BDL	3	BDL
7-29-95	06:24	67.6	BDL	11.4	84	91.2	12.8	38.3	367.3	893.8	3.9	8.8	14.5	132.2	1.9	57	9.1	6.4	238.4	XXX	XXX	0.8	XXX	BDL	XXX	BDL	BDL	0.6	BDL
8-1-95	09:09	NOT ANALYZED (WATER QUALITY SHIFT)																											
8-1-95	12:09	NOT ANALYZED (DILUTER MALFUNCTION)																											
8-18-95	08:33	NOT ANALYZED (SWITCHED TO CONTROL WATER)																											
8-18-95	13:48	NOT ANALYZED (POWER LOSS)																											
8-23-95	19:51	NOT ANALYZED (FISH DISEASE)																											
9-17-95	18:30	NOT ANALYZED (WATER QUALITY SHIFT)																											
9-17-95	19:15	NOT ANALYZED (WATER QUALITY SHIFT)																											
10-17-95	21:45	47.8	BDL	10.8	57.3	120	BDL	3.5	57.1	1050	1.4	8.4	43.7	47.1	2.4	27.8	6.6	8	305	XXX	XXX	0.5	XXX	BDL	XXX	BDL	BDL	BDL	BDL
10-26-95	22:15	46.2	BDL	3.5	25.2	150	BDL	2	48.5	10.6	1.5	11.4	9.7	36.7	2.8	49	5.9	23.7	272	XXX	XXX	BDL	XXX	BDL	64.6	1.6	BDL	BDL	BDL
11-3-95	13:58	60.5	BDL	1.7	29.6	163	BDL	BDL	BDL	41.9	1.2	8.6	8.5	31.1	2.3	107	6.8	9.7	306	BDL	BDL	BDL	BDL	BDL	61.7	1	BDL	BDL	BDL
11-5-95	15:42	62	BDL	2.8	16.5	187	BDL	BDL	BDL	39.6	0.7	24.5	8.3	40.2	2.5	113	6	10.4	356	BDL	BDL	BDL	BDL	BDL	63.8	2.1	BDL	BDL	BDL
11-7-95	07:57	60.5	BDL	3.1	32.7	178	BDL	1.4	5.3	48	0.8	11.2	10.6	39	2.5	101	6.3	9.7	342	BDL	BDL	BDL	BDL	BDL	61.7	1.7	BDL	BDL	BDL
11-9-95	11:43	59.8	BDL	8.9	28.5	138	BDL	2.2	10.2	47.5	0.8	6.9	11.3	37	2.2	73.9	5.9	10.3	314	BDL	BDL	BDL	BDL	BDL	55.7	1.5	BDL	BDL	BDL
11-15-95	06:42	NOT ANALYZED (WATER QUALITY SHIFT)																											
11-16-95	16:22	NOT ANALYZED (WATER QUALITY SHIFT)																											
11-17-95	14:24	46.4	1.8	7	20.3	105	0.8	1	32	BDL	5.8	5.9	20.5	58.4	2.7	66.7	7.8	8.4	245	1.2	XXX	BDL	0.9	XXX	55.1	13.4	BDL	BDL	BDL
11-17-95	15:09	47.1	1.7	6.3	15.8	103	0.7	0.8	32.2	BDL	5.7	3.4	21.7	44.2	2.7	68.1	7.7	8.4	243	BDL	XXX	BDL	BDL	XXX	61.2	8.5	BDL	BDL	BDL
11-18-95	05:54	46.1	1.7	5.9	19.9	106	0.7	0.9	38.9	33.3	5.9	3.7	19.8	48.6	2.7	79.6	8.5	8.9	277	BDL	XXX	BDL	BDL	XXX	64.7	8.7	BDL	BDL	BDL
11-26-95	23:54	42.8	1.7	4.9	15.1	102	0.5	1.8	35.8	BDL	5.7	3.2	16.4	33.6	2	120	3.4	7.6	234	BDL	XXX	BDL	BDL	XXX	45.4	3.7	BDL	BDL	BDL
11-27-95	01:39	43.8	1.7	4.2	12.6	105	0.5	0.7	35.7	BDL	5.7	3	14.3	37.9	2.1	126	7	7.5	237	BDL	XXX	BDL	BDL	XXX	48.2	2.5	BDL	BDL	BDL
11-27-95	03:24	44.4	1.7	4.4	12.1	106	0.5	0.6	35.2	BDL	5.7	2.8	12.9	39.2	2	124	7.6	7.4	239	BDL	XXX	BDL	BDL	XXX	45.3	1.3	BDL	BDL	BDL
11-27-95	05:54	44.7	1.8	4.6	9	118	0.7	0.7	32.5	BDL	5.8	2.9	13.7	34.3	2.2	128	7.9	7.6	237	BDL	XXX	BDL	BDL	XXX	45.3	1.3	BDL	BDL	BDL
11-27-95	06:39	44.5	1.7	4.2	11.3	106	0.6	0.6	34	BDL	5.7	4.6	16	43.9	1.9	126	7.4	7.4	234	BDL	XXX	BDL	BDL	XXX	46.4	0.9	BDL	BDL	BDL
11-27-95	13:39	43.9	1.7	3.9	16.8	106	0.6	0.8	32.5	BDL	5.7	2.3	18.1	33.9	1.9	139	8.3	7.6	239	BDL	XXX	BDL	BDL	XXX	44	0.8	BDL	BDL	BDL
11-27-95	16:54	42.9	1.7	3	22	109	0.6	0.8	28.6	BDL	5.7	2.2	16.7	28.6	2	140	7.6	7.3	245	BDL	XXX	BDL	BDL	XXX	46.2	0.7	BDL	BDL	BDL
11-27-95	18:54	43.7	1.8	3.1	17.3	123	0.7	0.8	28.2	BDL	5.9	3.3	13	30.9	2.3	141	7.7	7.7	247	BDL	XXX	BDL	BDL	XXX	44.3	0.7	BDL	BDL	BDL
11-27-95	20:39	42.8	1.7	2.9	23.1	109	0.6	0.6	30.4	BDL	5.8	1.5	14.3	28.8	2.1	140	7.2	7.8	243	BDL	XXX	BDL	BDL	XXX	46.1	0.7	BDL	BDL	BDL
11-27-95	23:54	43.4	1.7	2.9	20.8	123	0.6	1.2	30.4	BDL	5.8	1.9	15	32.3	2.2	140	7.3	7.8	242	BDL	XXX	BDL	BDL	XXX	47.1	0.7	BDL	BDL	BDL
11-28-95	16:09	43.8	1.7	2.4	14.2	109	0.6	BDL	36.7	BDL	5.9	2.3	12.4	65.9	2.3	140	7.8	8.5	247	BDL	XXX	BDL	BDL	XXX	48.2	0.6	BDL	BDL	BDL
11-30-95	04:39	43.1	1.7	4	16.4	115	0.6	BDL	45.1	BDL	6.2	1.7	12.6	54.9	2.3	142	7.5	7.7	238	BDL	XXX	BDL	BDL	XXX	50	0.6	BDL	BDL	BDL
11-30-95	07:24	43.2	2	3.1	14.8	103	0.8	0.6	41.5	BDL	6.4	1.7	10.5	44.7	2.7	139	7.5	8.4	245	BDL	XXX	BDL	BDL	XXX	44.5	0.6	0.5	BDL	BDL
11-30-95	13:54	43.3	1.7	4.4	7.2	113	0.6	BDL	41.6	BDL	6.2	2.3	11	53	2.4	122	7.4	8.2	243	BDL	XXX	BDL	BDL	XXX	45.9	0.5	BDL	BDL	BDL
11-30-95	14:24	42.5	1.7	4.2	10.2	99.9	0.6	BDL	45.1	BDL	6.1	1.9	11	57.5	2.3	121	7	8.3	246	BDL	XXX	BDL	BDL	XXX	47	0.5	BDL	BDL	BDL
11-30-95	15:54	41.8	1.7	4.2	9.4	99.2	0.6	BDL	41.6	BDL	6.1	2.1	10.1	65.5	2.4	127	7.8	8.2	249	BDL	XXX	BDL	BDL	XXX	48.8	0.6	BDL	BDL	BDL
11-30-95	21:39	42.4	1.7	4.1	7.7	101	0.6	0.6	43.9	BDL	6.1	1.6	10.3	58.4	2.3	127	8.7	8.1	242	BDL	XXX	BDL	BDL	XXX	48.8	0.6	BDL	BDL	BDL
12-1-95	00:24	42.3	1.7	4.4	12.9	99.8	0.6	BDL	44.6	BDL	6.1	1.9	9.6	53.8	2.3	118	6.9	8.1	240	BDL	XXX	BDL	BDL	XXX	46.7	0.5	BDL	BDL	BDL
12-1-95	05:54	43	1.7	5.6	17.4	115	0.7	0.5	49.1	BDL	6.3	2.8	11.4	64.9	2.3	119	7.8	8.2	276	BDL	XXX	BDL	BDL	XXX	48	0.5	BDL	BDL	BDL
12-1-95	07:54	42.5	1.7	5.3	14.8	100	0.6	0.6	49.2	BDL	6.2	3	12.8	59.7	2.4	122	6.6	8.3	243	BDL	XXX	BDL	BDL	XXX	51.1	0.6	BDL	BDL	BDL
12-1-95	09:24	42.2	1.7	5.4	17.9	100	0.6	BDL	47.7	BDL	6.2	2.3	13	57.9	2.2	121	7.2	8.3	238	BDL	XXX	BDL	BDL	XXX	48.8	0.5	BDL	BDL	BDL
12-1-95	10:24	NOT ANALYZED (SAME RESPONSE)																											
12-11-95	18:31	NOT ANALYZED (SWITCHED TO CONTROL WATER)																											

TABLE A6-1. CONTINUED

DATE	TIME	Li	Be	Mg *	Al	Ca *	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Mo	Ag	Cd	Sb	Cs	Ba	Hg	Tl	Pb	U
12-26-95	09:31	41.9	BDL	9.7	24.3	118	0.5	0.9	22.7	BDL	1.7	1.2	9.9	17.2	1.4	186	5.9	6.8	197	BDL	BDL	BDL	BDL	XXX	27.9	1.8	BDL	BDL	BDL
12-26-95	10:46	41.9	BDL	10.1	15.3	116	BDL	0.5	22.3	BDL	1.5	0.9	8.4	13.8	1.1	189	5.2	6.6	197	BDL	BDL	BDL	BDL	XXX	27.8	1.5	BDL	BDL	BDL
12-28-95	22:16	48.1	BDL	13.2	22.4	113	BDL	0.5	24.2	BDL	1.6	0.7	11.9	16	1	196	5.2	6.6	191	BDL	BDL	BDL	BDL	XXX	24	1.1	BDL	BDL	BDL
12-29-95	01:46	49.1	BDL	13	18	114	BDL	BDL	26	BDL	1.5	0.8	10.9	14.1	0.9	197	5.6	6.4	190	BDL	BDL	BDL	BDL	XXX	24.5	0.9	BDL	BDL	BDL
1-23-95	17:39	40.3	0.8	5.4	364	137	BDL	7.6	173	461	9.9	7	103	85.8	1.3	309	4.5	6.6	200	BDL	BDL	BDL	BDL	XXX	33.3	BDL	BDL	BDL	BDL
1-23-95	19:09	39.8	0.7	5.2	103	131	BDL	1.6	56.8	47.2	7.2	4.9	27.1	28.1	1.3	191	3.8	6.4	195	BDL	BDL	BDL	BDL	XXX	31.5	BDL	BDL	BDL	BDL
1-24-95	12:39	41.7	0.7	6.7	31.7	125	BDL	BDL	31.5	BDL	6.4	3.3	9.2	16.1	1.2	167	4	6.1	192	BDL	BDL	BDL	BDL	XXX	29.8	BDL	BDL	BDL	BDL
1-24-95	13:09	41.9	0.7	6.8	43	123	BDL	BDL	35.1	BDL	6.6	3.8	13.1	20.4	1.2	170	3.7	6.1	190	BDL	BDL	BDL	BDL	XXX	29.3	BDL	BDL	BDL	BDL
1-27-95	05:53	42.2	0.7	8.9	31	117	BDL	BDL	32.1	BDL	6.4	4.4	7.7	20.5	1.1	106	3.8	6	185	BDL	BDL	BDL	BDL	XXX	28.1	BDL	BDL	BDL	BDL
2-9-95	12:42	47.9	0.7	5.3	173	126	BDL	3.6	135	48.6	8.4	16.3	38	34.8	1	210	5	6.3	175	BDL	0.8	5.5	BDL	XXX	26.3	BDL	BDL	BDL	BDL
2-11-96	04:57	43.3	BDL	7.2	37.9	123	BDL	BDL	20.9	8.4	0	66.4	8.6	11.6	BDL	172	5.6	4.3	159	BDL	2	BDL	BDL	XXX	23.5	BDL	BDL	BDL	BDL
2-22-96	04:56	40.8	BDL	8.6	79.1	73.2	BDL	BDL	49.2	11.8	0.7	39.4	12.6	18.2	BDL	137	6.8	4.3	110	BDL	1.7	BDL	BDL	XXX	17.4	BDL	BDL	BDL	BDL
2-23-96	15:58	44.5	BDL	11.1	56.8	103	BDL	BDL	62.2	4.6	1.1	58.5	10.3	26.9	BDL	99.7	6.7	4.5	143	BDL	2	BDL	BDL	XXX	19.2	BDL	BDL	BDL	BDL
2-23-96	22:13	43.5	BDL	10.8	31.9	99.4	BDL	BDL	57.5	3.9	1	58.5	7.9	28	BDL	95.5	5.3	4.5	144	BDL	2.1	BDL	BDL	XXX	19.8	BDL	BDL	BDL	BDL
2-24-96	20:13	45.7	BDL	11.3	43	101	BDL	BDL	60.8	4.6	1	57	8.9	25.8	BDL	99.5	6.4	4.3	142	BDL	1.5	BDL	BDL	XXX	19.1	BDL	BDL	BDL	BDL
2-24-96	23:13	NOT ANALYZED (LOW TEMPERATURE STRESS																											
2-25-96	03:58	NO SAMPLES TAKEN (CONTROLS OUT)																											
2-25-96	06:28	NO SAMPLES TAKEN (CONTROLS OUT)																											
2-25-96	09:13	NO SAMPLES TAKEN (CONTROLS OUT)																											
2-25-96	23:43	NO SAMPLES TAKEN (CONTROLS OUT)																											
2-27-96	00:43	NOT ANALYZED (WATER QUALITY SHIFTS)																											
2-27-96	04:28	54.5	BDL	15.8	250	123	BDL	1	103	42.2	1.5	66.9	17	36.4	BDL	167	8.6	4.5	142	BDL	1.4	BDL	BDL	XXX	22.3	BDL	BDL	BDL	BDL
2-28-96	05:58	55.8	BDL	16.8	295	129	BDL	1.3	143	138	2.6	68	22	56.2	BDL	161	7.7	4.4	143	BDL	1.5	BDL	BDL	XXX	23.4	BDL	BDL	BDL	BDL
2-28-96	08:13	50.9	BDL	13.5	145	115	BDL	0.7	102	105	2	69.5	26.8	64.4	BDL	125	6.9	4	136	BDL	1.6	BDL	BDL	XXX	21.3	BDL	BDL	2.4	BDL
3-11-96	07:31	44.9	BDL	11.1	207	105	BDL	1.7	99.6	124	1.7	47.4	22.9	37	BDL	139	6	5.2	162	BDL	1.3	BDL	BDL	XXX	20	1.9	BDL	BDL	BDL
3-11-96	09:57	46.4	BDL	11.1	319	108	BDL	2.4	112	246	2.1	46.8	32.1	46.6	BDL	168	6.3	5.1	160	BDL	1.4	BDL	BDL	XXX	20.2	1.1	BDL	BDL	BDL
3-11-96	11:57	47	BDL	10.9	231	104	BDL	1.8	86.8	158	1.6	47.9	24	34.1	BDL	143	6.3	5	157	BDL	1.4	BDL	BDL	XXX	19.8	0.8	BDL	BDL	BDL
3-27-96	06:14	49.3	BDL	8.4	111	121	BDL	0.8	55.8	15.6	1.4	57.4	6.2	27.7	BDL	128	6.1	8.4	162	BDL	1	BDL	BDL	XXX	17.7	BDL	BDL	BDL	BDL
3-27-96	08:59	48	BDL	8.5	120	120	BDL	0.8	54.6	14.5	1.3	58.5	5.1	24.7	BDL	132	6.3	8.4	162	BDL	1	BDL	BDL	XXX	17.6	BDL	BDL	BDL	BDL
3-27-96	15:14	47	BDL	10.3	86.6	109	BDL	0.8	56.8	14.8	1.3	54.6	5.4	22.9	BDL	146	7.4	38	163	BDL	1	BDL	BDL	XXX	21.2	BDL	BDL	BDL	BDL
3-28-96	08:59	43.2	BDL	9.1	224	103	BDL	1.2	87.9	155	2.5	53.1	12.2	42.9	BDL	152	6.5	13.2	147	BDL	1	BDL	BDL	XXX	19	BDL	BDL	BDL	BDL
3-28-96	10:14	42.5	BDL	8.8	188	102	BDL	1	77.9	121	2.1	49.6	10.1	38.4	BDL	143	6.7	13	147	BDL	1	BDL	BDL	XXX	19.6	BDL	BDL	BDL	BDL
3-28-96	17:44	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-28-96	18:14	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-28-96	19:44	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-28-96	22:29	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-29-96	05:59	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-29-96	07:59	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-29-96	16:44	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-29-96	17:59	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-30-96	13:44	38.4	BDL	9.1	56.3	108	BDL	1.1	48.3	20.3	1.1	52.6	4.8	39.2	BDL	143	6.1	7.6	153	BDL	0.9	BDL	BDL	XXX	22	BDL	BDL	BDL	BDL
3-30-96	21:14	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-30-96	23:59	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-31-96	01:44	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-31-96	03:29	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-31-96	05:14	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-31-96	14:29	NOT ANALYZED (WATER QUALITY SHIFTS)																											
3-31-96	16:59	NOT ANALYZED (WATER QUALITY SHIFTS)																											